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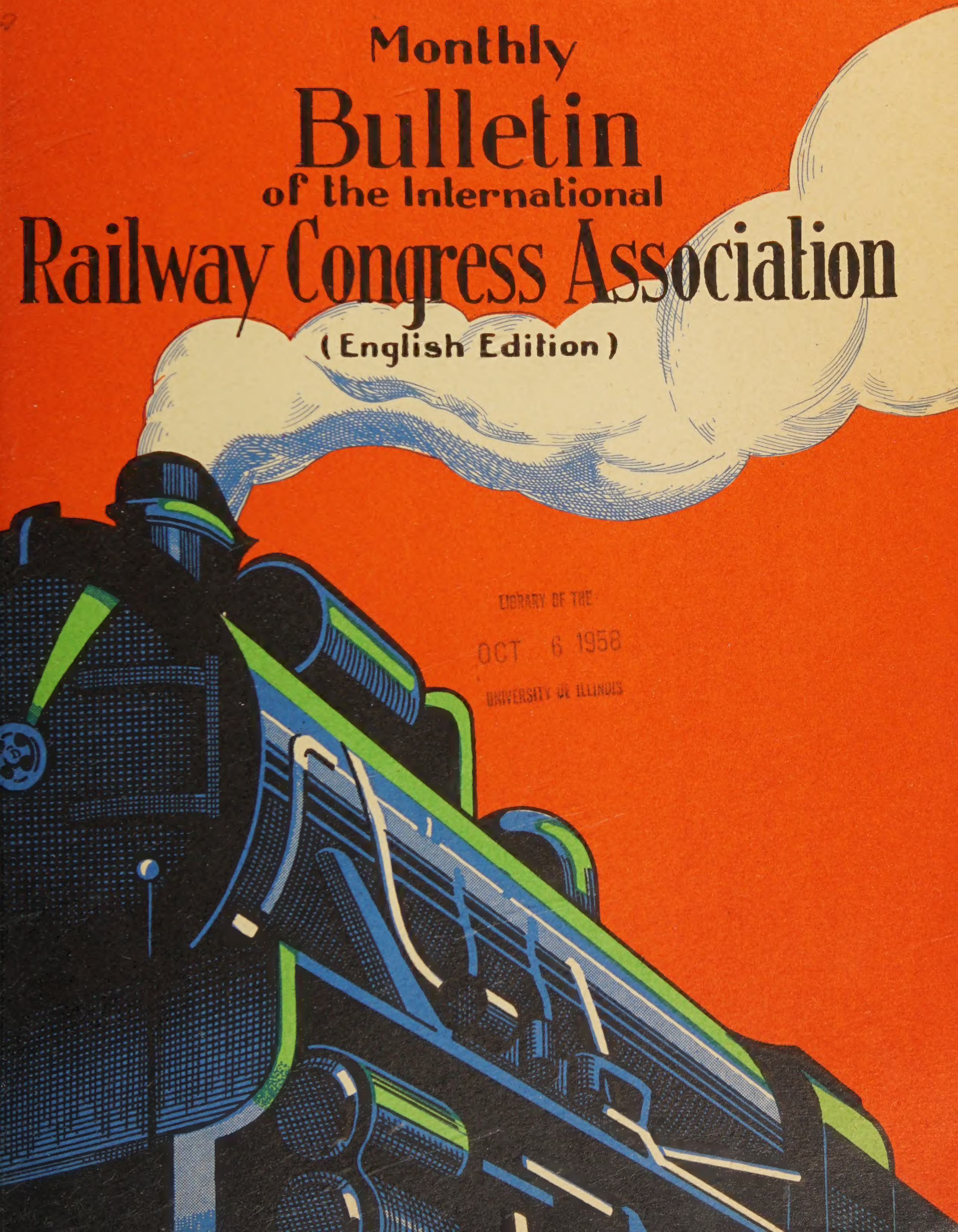
(English Edition)



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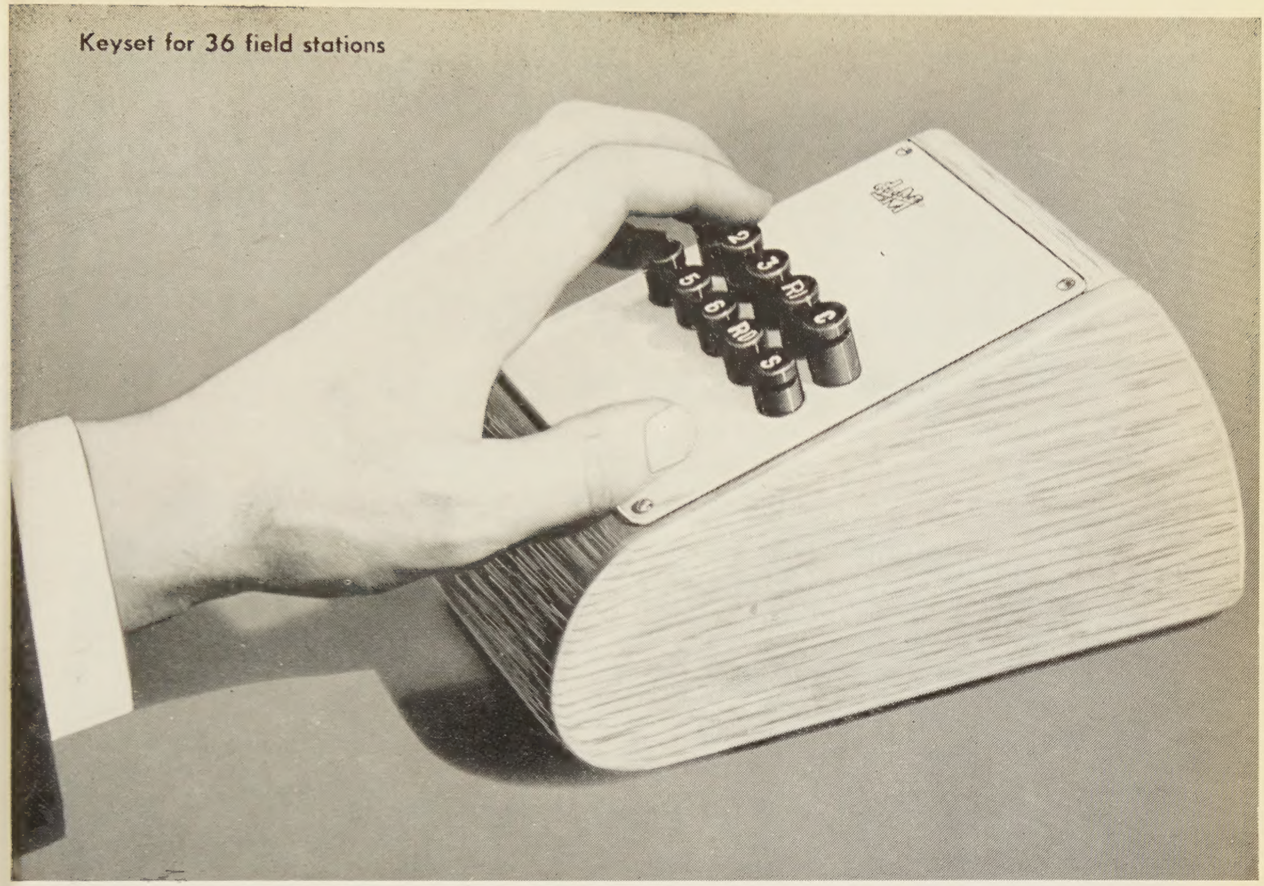

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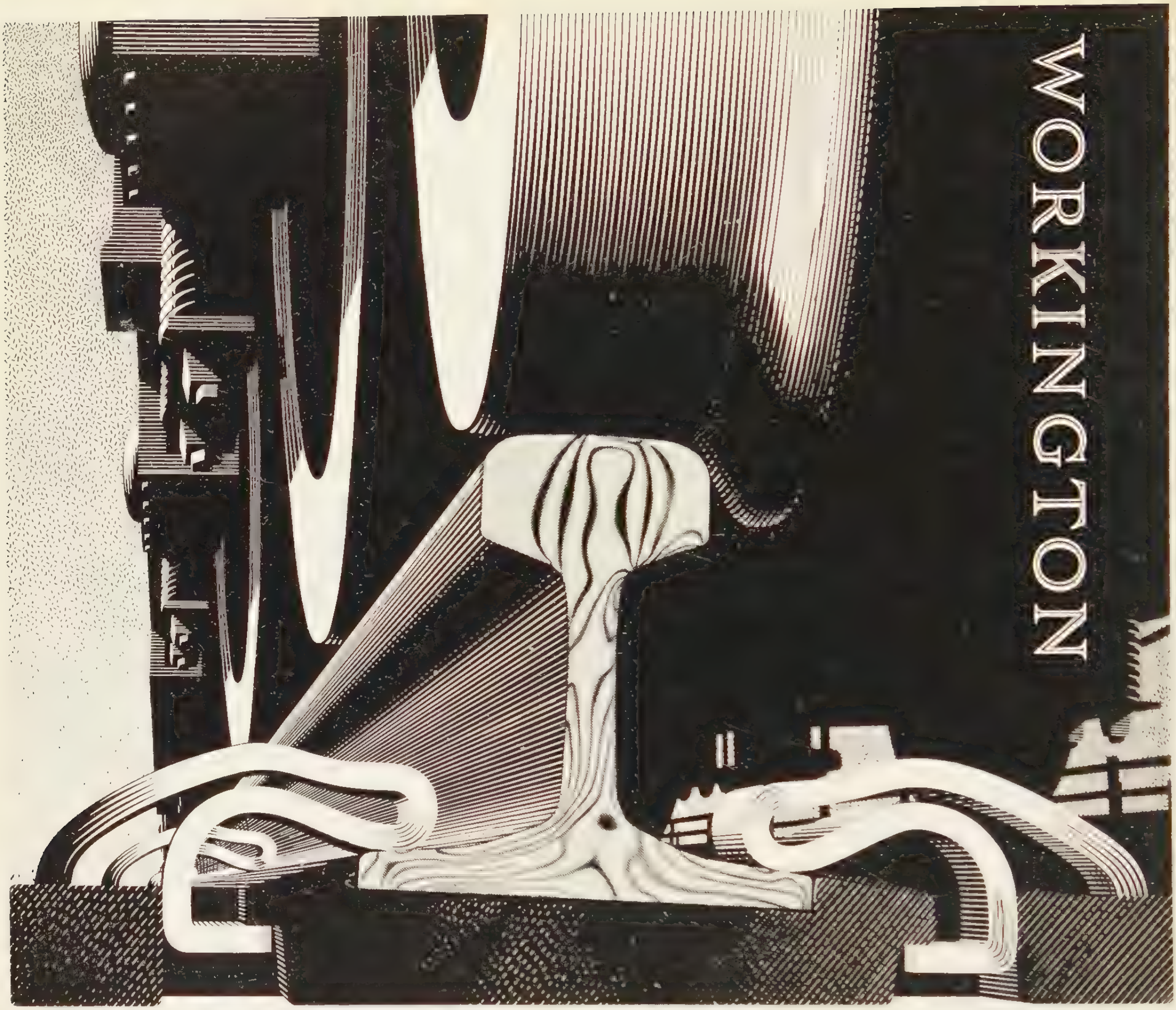
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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

SPECIAL ACCOUNTS

summing up the reports on the questions for discussion at the seventeenth Session of the International Railway Congress Association (Madrid, 1958).

SECTION I. — Way and works.

[624]

QUESTION 1.

Problems presented by the ageing of bridges and viaducts. Long term effects of fatigue and corrosion in steel bridges and weathering of masonry.

Rational methods of maintenance of bridges.

Repair and strengthening,

by Dr.-Ing. G. Cividalli,

Inspecteur en Chef Supérieur au Service de la Voie et des Constructions des Chemins de fer de l'Etat Italien.

Special Reporter.

Question 1 has been covered by the two following reports :

Report (America (North and South), Australia (Commonwealth of), Austria, Burma, Ceylon, Egypt, Western Germany, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories, by Fr. Lemmerhold. (See « Bulletin » for May 1958, p. 639.)

Report (Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yougoslavia), by Dr.-Ing. G. Cividalli. (See « Bulletin » for June 1958, p. 821.)

The object of the present report is to sum up the main features of these reports and endeavour to formulate some summaries from them.

The questionnaire drawn up by the reporters was sent to 109 Administrations. Forty-two Administrations replied, some of them with extensive information.

We wish to take this opportunity of tendering our hearty thanks to these Administrations who made it possible for the reporters to prepare reports which would contribute towards solving the problems dealt with.

The questionnaire contained 63 questions divided into four chapters :

1) General considerations;

2) Metal bridges;

3) Masonry and concrete bridges and viaducts;

4) Inspection and maintenance of bridges.

This subdivision will be retained in the case of the present report.

CHAPTER I.

GENERAL CONSIDERATIONS.

A) *The life of bridges.*

In studying new bridges, it is not as a rule the custom to set a precise length of life, and in selecting the type of bridge to be built, the idea of its life is only the final consideration, other more imperative factors (admissible thickness of the deck, facilities for obtaining materials and carrying out the work, time taken to build the bridge, operating requirements) being given priority consideration.

In fact, if the economic suitability is calculated on the basis of financial mathematical formulae, one comes to the conclusion that the presumed life of the bridge has very little importance from the point of view we are here considering.

Naturally, this conclusion is only valid in the case of steel, masonry or concrete bridges, built in such a way as to assure that they will have the longest possible life.

Apart from this conclusion, in the replies received the following essential points emerge :

1) The life of metal bridges is expected to be between 50 and 100 years;

2) The life of concrete bridges is expected to be 40 years according to the A.A.R. (Association of American Railroads), 75 to 100 years according to most of the other Administrations, 120 years in the case of beam bridges and 200 years in the case of arched bridges according to the Czechoslovakian Railways, and is considered limitless by the Matadi-Leopoldville Railway (Belgian Congo);

3) As for masonry bridges, these are expected to have a life of 100 years or longer, or even without limit.

These estimates, in the case of masonry bridges, are confirmed by a wide experience.

It is very different in the case of metal bridges, not only because many of these bridges have had to be replaced or strengthened owing to the increase in the loads, but also the question arises of deciding whether the observations made in the case of old bridges, nearly all made of puddled iron, are valid for bridges built more recently of steel with different and more careful working methods and according to new constructional arrangements.

In the same way, experience in the field of reinforced concrete bridges is still insufficient at the present time.

Several Administrations report in their replies estimates made with the sole object of introducing sinking fund rates for the installations in their budgets.

In general, such estimates make no distinction between the different types of structures and the sinking fund rate varies between 1 and 2 %, i.e. the presumed life varies between 100 and 50 years.

B) *Cost of maintenance and renewal.*

In general, the annual sums required for the maintenance of bridges are determined according to the condition of the bridges as confirmed by inspection and according to the experience acquired during recent years.

In the same way, the budget provisions for the renewal of bridges are based on actual requirements and according to the programme for the modernisation of the lines, taking financial possibilities into account.

Several Administrations allocate the amounts for maintenance and renewal in relation to the total value of the bridges, but the basic principles upon which they base such estimates vary from one to the other.

The rates adopted for maintenance and renewal are sometimes the same for all types of bridges.

Some Administrations however fix different rates according to the type of bridge.

About 50 % of the railways state that they are unable to carry out regular maintenance of their bridges owing to lack of funds.

CHAPTER II.

METAL BRIDGES AND VIADUCTS.

A) *Verifying the stability.*

All the Administrations consider that the progressive increase in the loads makes it necessary to recalculate existing metal bridges to see whether the proposed new loads are admissible.

Such calculations must take into consideration the state of conservation of the bridges and the stresses which may be caused by erroneous constructional arrangements.

In certain cases, it is absolutely necessary for the results of these calculations to be completed by actual trials.

Eight Administrations determine the carrying load of each component of an old bridge in the form of a percentage of their standard type train for new bridges.

The other Administrations proceed to check the bridges with a different standard type train or — and this is the most frequent case — the real load for each train which has to be taken into account.

The opinions of the Administrations vary widely regarding the admissible stress limits for old bridges.

Certain Administrations in their verifying calculations allow the same stress limits as on new bridges; others make no distinction between old and new bridges, but adopt different safety limits for different materials, whilst still others increase the admissible stress limits for old bridges by a proportional percentage; finally, there are some Administrations who apply different limits in each case determined according to different principles.

The effects of fatigue are taken into consideration by certain Administrations by lowering the admissible stress limits as a function of the ratio between the maximum and minimum stresses in all the elements or — most frequently — only in the zones where the stresses are reversed.

This method is used in calculating both old and new bridges.

Certain Administrations consider that checking the state of conservation of a metal bridge, which should be done at the same time as the verification calculations, should also take into account the possible ageing of the materials.

B) *Tests.*

None of the Administrations concerned has carried out systematic trials of the metal components used in the construction of bridges nor on the metal bridges themselves, in order to ascertain whether there has been any ageing of the materials.

Several of the Administrations consulted have reported technological tests carried out on components of old bridges but most of them consider that modifications in the presumed characteristics of the materials at the time they were used cannot be checked except at those places where such elements have undergone strain hardening.

This opinion is not shared by all the Administrations.

The F.S., for example, consider that the characteristics of puddled iron may deteriorate as a result of ageing.

C) *Methods of examining metal bridges.*

It must be supposed that several Administrations did not indicate all the methods they use.

We think that nearly all the Administrations carry out visual inspections, mechanical examination by hammer of rivetted assembling, measuring of the deflections and stresses, and an examination by X rays to check the weld runs.

Other methods of examination (tests with pulsating machine, ultrasonic tests, inspection by magnetic processes, etc.) are used less frequently and perhaps only by those Administrations who expressly mentioned them.

D) *Types of deterioration and their causes.*

Opinions differ as regards deterioration due to fatigue.

According to some Administrations such deterioration cannot be ascertained and even the cracks and breaks which occur in certain badly proportioned or constructed elements can be attributed to excessive stresses which result from these defects in design or execution; the possibility that to such stresses must be added an actual effect of fatigue is merely a hypothesis, which is not impossible but which has not been proved by experience either (S.N.C.F.).

Other Administrations on the contrary affirm that deterioration due to fatigue is often met with.

Except for damage due to accidental causes (derailments, excessive size of loads, collision with movable objects), the damage usually noted can be attributed to a combination of several causes.

Amongst these causes, defects in the materials are placed last by all the Administrations, whereas faults in design and defects in construction are reported in particular in the case of old bridges.

Rust is the most serious enemy of metal bridges, but its action becomes manifest when the maintenance is not suitable for the locality in which the bridge is built, above all in those parts which are difficult of access, exposed to dirt, insufficiently ventilated or likely to retain water.

The action of rust is favoured by an excessive distance between rivets.

The elements chiefly affected by corrosion are those near the supports, the lower chord members in the form of a U, the bearing plates or upper flanges of the longitudinal girders (particularly in those places carrying the sleepers for the track), the flanges (especially in the assembly of the windbracing to the chord members), the sheets and plates of the decking.

Most of the Administrations report that they encounter special difficulties in preserving watertight decks from corrosion.

Loose rivets have been found in all parts of bridges, but this defect is more frequent in the case of multiple trellis girders, in the assembly of the windbracing to the main beams and above all in the assembly of the longitudinal girders to the cross stays.

The presence of cracks attributable to fatigue is usually limited to these same places.

E) *Steps taken in the case of serious deterioration affecting the strength of bridges.*

The first step taken by all the Administrations is to reduce the speed.

Most of the Administrations have applied other measures in turn: temporary repairs, introduction of temporary elements or supports, replacing faulty bridges by temporary bridges. It is only as a last resort that they reduce the loads allowed.

F) *Protection of metal bridges against corrosion: painting.*

Painting is mentioned by all the Administrations as the most usual method of protecting metal bridges against corrosion.

Good results from painting depend in the first case on the care with which the surfaces to be protected are prepared.

The methods used to clean and remove the old paint and rust are more or less the same in every country : hammering, scraping with metal brush, sanding in difficult cases and sometimes even burning off.

With the exception of two railways (Ö.B.B., R.E.N.F.E.), all the Administrations consider that the regulations covering the preparation of the surfaces to be painted are adequate.

In general, painting of metal bridges includes :

— one or two coats of undercoating;

— two (sometimes 1 or 3) protective coats.

Red lead paint is generally used for the undercoating.

The protective paints used vary considerably. At the present time use is made of zinc white, white lead, micaceous iron oxide, aluminium, bitumastic paints, etc.; the latter appear to be the most efficacious for parts exposed to acids and smoke.

The medium most used is boiled linseed oil, but certain Administrations also use synthetics.

Some Administrations use special paints for special site conditions : in particular paint with a bitumastic or tar base. Other Administrations in such special cases have made trials of special paints having a vinylitic resinous base, lead metal, chlorated rubber, etc.

Opinions vary concerning the precautions to be taken to protect surfaces permanently in contact.

Most of the Administrations protect such surfaces by a coat of undercoating as used on the rest of the bridge; others make use of a different type of paint, whilst still others do not require such surfaces permanently in contact to be painted, or even forbid them to be painted, especially in the case of welded assemblies.

The A.A:R. and D.B. recommended that surfaces in contact should not be covered with paint when high tensile steel bolts are used for assembly.

G) *Conservation of the paintwork — repainting.*

The conservation of the paintwork depends upon site conditions and definite differences in the way the paint stands up have been noted even in the case of bridges very close to one another, and even in different parts of the same bridge, as a result of the different degrees of exposure to wind, rain and sun.

The action of smoke from the locomotives is particularly harmful to paintwork.

The proper conservation of the paintwork is favoured by choosing bridges with smooth, plain surfaces, without any discontinuity of line.

The average period between two successive repainting varies considerably according to site conditions. In countries very close to the sea, in very industrialised regions, or in equatorial countries with a humid climate, this period may be only two or three years, whereas it may be as much as 30-40 years in mountain regions where the air is particularly pure.

Eleven Administrations replied that they repaint at regular intervals laid down in advance. All the other Administrations fix the dates for repainting according to the condition of the paintwork.

In general, when the period between two repaintings is very short, only summary or partial repainting takes place.

The D.S.B. are a very interesting exception : every summer they partly overhaul the paintwork of certain bridges in particularly exposed positions and in this way manage to extend to 10 years the period between one complete repainting and the next.

When the period between two repaintings is very long, the need to undertake partial repainting occurs, and this is often done during the periodic minor maintenance work.

H) *Methods of protecting metal bridges other than painting.*

Twelve Administrations make use of metallisation, but in general this process

has been limited to certain given elements, in particular the embedded sheets of the decking.

Only four Administrations (A.A.R., B.T.C., D.S.B. and S.Ap.R.) have used metallisation on a larger scale.

Other processes mentioned are :

— applying zinc powder by pulverisation or by brush, as a cathodic protection on a basis of linseed oil or synthetics;
— the protection of metal parts exposed to smoke by encasing them in concrete;
— the use of chrome or copper steel.

Such steels were given a trial some time ago by the S.N.C.F. and more recently by the D.S.B. However, the alloys have not shown any noticeable improvement on the need for good maintenance.

The M.A.V. use copper steel for the sheeting of watertight decks with ballast. The results are satisfactory.

No other Administration has made use of rustless steels or other metals or alloys in order to avoid corrosion.

I) *Repairing and strengthening metal bridges.*

Repairing metal bridges weaked by corrosion of cracks is done by replacing the parts that have deteriorated when possible, or by strenghtening such elements by assembling new profiles or sheets which are rivetted, bolted or welded to the damaged elements.

The use of welding to repair and strengthen bridges is still the subject of much discussion.

Whereas certain Administrations report that welding is not used or even not allowed for this purpose, because the results have not been considered satisfactory, other Administrations frequently use it (even to repair and strengthen puddled iron bridges) and state that the results have been very good.

Only a few Administrations report carrying out strengthening of bridges in order to eliminate defects in design or construction; nearly all on the other hand have strengthened metal bridges in order to enable them to carry heavier loads than those for which they were originally designed.

Such strengthening can be carried out by the addition of new elements (construction of additional supports, adding one or two additional main beams, adding two arches above or two trusses below the main beams, adding a concrete deck, doubling the number of cross stays) or by reinforcing the sections of existing elements and assemblies.

Opinions differ regarding the advantage of strengthening metal bridges, especially in the case of old puddled iron bridges, which the S.N.C.F. is now reinforcing, whereas according to other Administrations it is not advisable to strengthen bridges built of this iron.

In the case of steel bridges, strengthening may be advantageous when the condition of the bridge is satisfactory, and the reinforced bridge can be expected to have a sufficiently long life.

Deciding whether to build a new bridge or strengthen the existing bridge should only be done after comparing the cost involved, including all the supplementary and indirect costs (such as the upset to the working) which in the case of reinforcing are often considerable and difficult to estimate.

The probable life of the reinforced bridge and future maintenance costs must also be taken into account, as the latter are generally greater in the case of a reinforced bridge than a new bridge.

CHAPTER III.

MASONRY AND CONCRETE BRIDGES AND VIADUCTS.

A) *Types of deterioration and their causes.*

Whereas the German Federal Railways and the Viet-Nam Railways gave the per-

centages for the frequency with which various causes of damage occur, other Administrations found it difficult to get any definite classification of the causes of damage and their importance, in view of the fact that the same damage can be attributed according to the case and different points of view either to defects in design, defects in the materials, poor execution of the work, etc.

The lists of damage reported by the Administrations are often very long.

The most important types of damage reported by the greater number of Administrations are :

— the formation of cracks, the main causes of which are first of all inadequate foundations or earthworks and subsidence of the soil, and then the absence of expansion joints, an insufficient layer of ballast, defective transversal joints in the case of bridges made of encased girders, the different degrees of rigidity of the various parts of the bridge;

— breaking and scaling of the surfaces, generally due to the use of bricks or stones with insufficient strength to stand up to the weather;

— the crumbling of the mortar and the disintegration of the masonry, generally attributable to lack or insufficiency of water tightness;

— the disintegration of the concrete or laying bare of the reinforcement, the causes of which may be the use of too much water in the mix, insufficient covering or badly arranged reinforcement, the action of smoke from the locomotives, defective granular consistency of the concrete and poor quality aggregates.

Lack of maintenance is not in general considered to be the cause of much damage.

However it must be stressed that renewing the watertight casing in good time and regularly cleaning out the drain outlets is extremely important for the good conservation of bridges, whereas such work which is expensive to carry out, is often put off or prevented owing to operating needs and financial difficulties.

B) *Methods of inspecting masonry and concrete bridges.*

The methods generally applied are careful visual inspection, checking the breaking of test pieces, noting relative displacements of the marks, periodic checks of the levels, and sounding by hammer blows.

In certain cases, when it is suspected that the interior of a massive element has disintegrated, several Administrations make use of special methods : use of pachymeters, ultrasonic equipment, X rays, etc. In general, no railway has reported any really satisfactory solution which is not destructive. Only the Czechoslovakian Railways report a method of measuring directly the speed of propagation of impulses which makes it possible to sound arches up to one metre thick.

C) *Casings.*

Five Administrations do not waterproof at the present time, obviously on account of the favourable climatic conditions in their countries; three Administrations are of the opinion that it is unnecessary to provide a special casing on concrete bridges provided the concrete is sufficiently compact.

Other Administrations think that casings are unnecessary in the case of bridges made of longitudinally and transversally prestressed concrete or when the track is laid directly on the concrete without any ballast.

When there is no casing, it is absolutely essential to assure rapid drainage of any water.

Apart from these special cases, the use of a casing is generally recommended, but the types of casings used vary a great deal.

The railways of Spain, France and the French Union generally make use of cement casings, whereas most of the other Administrations use an asphalt covering or multilayer casings consisting of cardboard or

jute or glass wool material used as a foundation for bitumastic products.

In certain cases, metal sheets, generally copper, are also used.

Three Administrations (Ö.B.B., D.B. and C.F.L.) report the use of casings made of synthetic plastic materials, which to date have given satisfactory results.

The thickness of the casings varies a great deal according to the type adopted and the position of the surfaces to be protected. In this connection, it must be reported that the R.E.N.F.E. do not extend the casing to the spandrel walls; other Administrations, amongst them the S.N.C.F. carry the casings up in such a way as to assure proper protection, whilst on the bridges of some railways they are taken up over the whole height of the sides of the spandrel walls.

Very few Administrations gave any details about the arrangements adopted for the casings at the deck joints.

Most of the Administrations report that it is absolutely essential to cover the casings with a protective waterproof coat, with the exception of course of cement casings which often are not protected.

The protective coat is generally made of concrete or mortar (reinforced or not with a metal trellis). In certain special cases, ceramic tiles or hardened bricks are used to protect the casing.

The minimum thickness (beneath the underside of the sleepers) to be given to the layer of ballast in order to avoid damage to the casings due to carrying out work on the line and to localised stresses varies considerably from one Administration to another (from 10 to 60 cm = 4″ to 1′ 11 $^{5}/_{8}$″).

The life of the casings is very variable and is influenced not only by their nature and the care taken in making them, but also by the nature of the filling in between the spandrels, the efficiency of the drainage arrangements, and above all the fatigue affecting the components they protect.

The B.T.C. and D.B. estimate that the life of modern casings may be more than 100 years.

D) *Repairing or strengthening masonry and concrete bridges.*

In the replies received from the Administrations the following work was mentioned :

Replacing stage by stage defective stones or bricks, repointing, grouting with cement, replacing loose filling in by thin concrete, renewal of the casings, adding metal or reinforced concrete trusses, seams, replacing the old masonry by new masonry, renewing deteriorated concrete, strengthening the arches, decks and abutments by a reinforced concrete covering, propping up, centering, consolidating the foundations by grouting with cement mortar, underpinning, etc.

There is no doubt that some of the work mentioned, which was only mentioned by some Administrations, is done much more often than would appear from the replies.

It should also be noted that in general such steps are not taken by themselves and in most cases use is made of methods resulting from a combination of several of the measures quoted.

We have already mentioned the fact that renewing the waterproofing in good time is sometimes prevented by operating requirements.

Consequently certain Administrations, when there is any danger of the masonry or concrete deteriorating due to the inadequacy of the casing, have endeavoured to carry out waterproofing work to or through the soffits of the arches.

Such work (thorough repointing, grouting with cement, applying to the soffits either a watertight coat of cement mortar reinforced or not with a metal trellis, or a layer of concrete, covering with copper sheets protected and held in place by a layer of concrete) have given fairly satisfactory results : in certain cases the seeping through of water has been completely stopped and in general permeabily is considerably reduced.

Most of the Administrations think that old masonry bridges which are in a good

state of repair are capable of carrying much higher loads and greater speeds than those for which they were built, and that such loads and such speeds can generally be allowed after a very careful check of the condition of the bridges.

Only three Administrations, the Danish State Railways, Viet-Nam Railways and Norwegian State Railways, are of the opinion that when increasing the loads a static examination is advisable.

Some Administrations reported reinforcements carried out with the sole object of allowing heavier loads to pass over the bridge than those provided for at the time the bridge was designed, but these are exceptional cases.

The principal work with this object in view is :

— reinforcing the piers and abutments by a thick layer of reinforced concrete, sometimes prestressed up against the old masonry;
— the construction of a new arch under or over the old one;
— the use of a deck or reinforced concrete slabs suspended in the ballast in order to distribute the load better.

Repairing or strengthening the arches involves special precautions to assure a proper distribution of the stresses.

Provided it is only a question of limited renewals, it is generally considered sufficient to assure proper solidarity between the old and new masonry by anchoring irons or seams; but when it is question of important renewals, it is necessary to centre the arch and make use of jagging.

In special cases, the S.N.C.F. has even made use of keystones made in expansible concrete.

In the case of work of reinforcing, when it is not possible to take the load off the existing bridge, it is necessary to take into account the unequal distribution of the stresses, when dimensioning the reinforcement itself.

Although some Administrations consider that partial reconstruction is not satisfactory and complete remaking of the arches is more economic, most of the other Administrations state that the choice between partial or complete reconstruction depends upon the condition of the bridge and a comparison of the costs, and that partial reconstruction of the arches is to be recommended if this only affects a relatively small part of the bridge and provided the condition of the remainder of the arch, abutments and foundations is such that the bridge can be expected to have a long useful life.

It should be noted however that operating requirements in some cases may make it impossible to rebuild an arch completely and oblige the Administrations to carry out reconstruction and reinforcement work to the masonry even though this costs more, rather than rebuild completely.

CHAPTER IV.

INSPECTION AND MAINTENANCE OF METAL, MASONRY AND CONCRETE BRIDGES AND VIADUCTS.

The organisation of bridge inspection differs greatly from one Administration to another.

This inspection may be the responsibility of the district permanent way inspector or of inspectors attached to the regional services or the bridges department of the central Administration of the railway.

Some Administrations leave the inspection of the less important bridges to the district permanent way inspector, whilst inspectors attached to the special services are responsible for inspecting and checking the important bridges. Other Administrations order annual inspections to be carried out, which are the responsibility of the permanent way staff, with more thoroughgoing inspections at longer intervals by the inspectors of the bridges department. The latter inspections are sometimes only required in the case of reinforced concrete bridges and metal bridges, or even only in the case of metal bridges.

The methods used for current maintenance are also very different. Certain Administrations possess bridge maintenance gangs, generally specialists in the maintenance of metal bridges.

The size and equipment of these gangs are very variable, as well as the importance of the work for which they are responsible.

Some Administrations have gangs responsible for work of lesser importance, with other gangs specialising in general overhauls. Some also have fixed or even mobile repair shops.

The Administrations who have no gangs to carry out their own repairs or who only carry out small maintenance jobs then entrust these to the permanent way staff and certain qualified workmen.

Administrations who have such gangs generally do some of the work for themselves and contract out the rest to private firms; but the way the work is divided up differs considerably from railway to railway.

Certain Administrations do all the maintenance work themselves.

When a contractor is given any maintenance job, he usually supplies all the material required. There are some exceptions however: there are in fact some Administrations which prefer to supply the materials needed to the contractor, especially the paint to be used for repainting metal bridges.

SUMMARIES.

1. — It is not possible to forestell the life of a bridge when building it solely on the experience acquired from observing existing bridges.

Best quality materials, the most careful methods of calculation, and new constructional methods lead us to think that the life of new metal and reinforced concrete bridges will be very long, provided they are suitably maintained.

The importance, from the economic point of view, of the life of a bridge is generally not very great and the choice of a type of bridge when it is being planned is determined by other more imperative considerations: cost, operating requirements, maintenance costs.

2. — Several Administrations fix the budget allocations for maintenance and renewal as a function of the total value of the bridges; but most of them determine these sums from the condition of the bridges and the experience they have acquired, taking into account their financial possibilities, which often make it impossible to carry out the maintenance work properly.

3. — The progressive increase in the loads generally makes it necessary to check by calculation existing metal bridges in order to decide if they can take the new loads proposed.

The opinions of the Administrations differ as to the proper interpretation of the technological tests which have been carried out on elements from old metal bridges. The stress limits allowed for such bridges vary considerably from one Railway to another.

4. — To examine metal bridges the Administrations generally make use of sounding by hammer in the case of rivetted assemblies, and measuring the deflections and stresses as well as the use of X rays to check the welds. New processes, such as those based on ultrasonic equipment or magnetisation have already been given a trial on several Railways.

5. — Good conservation of metal bridges necessitates above all protection against corrosion, which occurs especially at those points which are difficult of access, exposed to dirt, insufficiently ventilated, or likely to collect water.

Consequently, when designing new bridges it is essential to select smooth, simple designs, and adequate constructional arrangements; in addition bridges should be maintained regularly.

6. — Careful painting and regular repainting, carried out after proper prepara-

tion of the surfaces (hammering, scraping with metal brushes, in difficult cases descaling by sand jet and sometimes burning off) are the most currently used methods for protecting metal bridges against corrosion.

In general, the paint used is the classic red lead, iron, or chromate of zinc paint (undercoats) and white zinc, white lead, iron oxide, and aluminium paints, or those with a bitumastic or tar base (protective paints).

It is not yet possible to formulate any valid opinions concerning the trials made of special paints based on new formulae (with a vinylitic resine base, lead-metal, chlorated rubber, etc.) which some railways have started to use.

7. — In the opinion of most of the Administrations in the case of rivetted structures, surfaces permanently in contact should be protected by a coat of paint.

In the case of welded structures, on the contrary, this practice may be given up owing to the preparation of the welds.

In addition, it is recommended not to cover these surfaces with paint when high tensile bolts are used for assembly.

8. — Where local conditions are particularly unfavourable, it is necessary to repaint every two years, whereas intervals of 30 to 40 years between repainting may be possible in certain mountain districts where the air is pure and dry.

Partial repainting makes it possible to increase the intervals between two complete overhauls.

9. — Methods of protecting metal structures other than painting (metalisation, cathodic protection, use of rustless steel and other metals or alloys) have only been used in special cases.

Encasing in concrete metal parts exposed to the smoke from locomotives is the current practice on certain Railways; in particular mention must be made of the use of prefabricated concrete or asbestos cement components, which appear to give complete satisfaction.

10. — Metal bridges are repaired either by replacing damaged parts when possible, or by reinforcing these elements by adding new profiles or sheets by rivetting, bolting or welding. In cases like this, the advisability of using welding is still queried.

11. — The all over reinforcement of metal bridges can be obtained by adding new elements, or by strengthening the sections of existing elements or their assemblies.

The majority of Administrations prefer to renew bridges completely rather than carry out large scale reinforcing operations, especially in the case of old iron bridges.

In the case of steel bridges, the choice between building a new bridge and reinforcing an existing bridge must be settled by comparing the cost of the different possible types, including the supplementary or indirect costs, and a conservative estimate of the life of the reinforced bridge, together with the expected maintenance costs, which are generally higher in the case of a reinforced bridge than a new bridge.

12. — The construction of masonry and concrete arched bridges must be avoided when it does not appear possible to keep the pressure on the soil within limits compatible with a wide margin of safety.

The success of reinforced concrete bridges depends upon using good quality aggregates with suitable granular structure. The water content should not be too high. The arrangement of the reinforcement metal must be carefully studied and executed, and it must be properly covered.

13. — The condition of masonry and concrete bridges is generally checked by a visual inspection, noting any possible displacement of the reference marks, inspecting test pieces, periodically checking the levels, sounding the surface with a hammer; other special non-destructive methods have been given trials, but none of them appear to furnish any certain information concerning the condition of the bridges deep down.

14. — Good conservation of masonry and concrete bridges is only possible if they

are sufficiently water tight and have effective drainage systems. These conditions appear to be realised without difficulty in the case of bridges made of longitudinally and transversally prestressed concrete, as well as bridges on which the track is laid directly on the concrete without ballast, where the water quickly drains away. Apart from these special cases a waterproof casing is to be recommended.

Cement mortar casings can give good results when the structures they protect are sufficiently rigid; but in general flexible casings are preferred, made of asphalt or consisting of several layers of material or cardboard impregnated with bitumastic materials, or even metal sheets (generally copper) or plastic materials.

In view of the importance of the casings for the proper conservation of the bridges and the difficulties encountered in renewing them, it is necessary to try and get casings which will last as long as the bridges they protect. In this connection, the recent introduction of plastic materials has to date given satisfactory results. It is possible to hope that the use of thermo-plastic materials will make it possible to obtain this result, provided the casing itself is suitably protected against damage of a mechanical nature.

For this purpose, the use of a protective coat, generally of concrete or asphalt putty is to be recommended.

15. — If the masonry or concrete bridge is threatened with deterioration due to a lack of watertightness and when operating reasons prevent the carrying out of repairs to the casing, waterproofing processes may be used applied to the soffits or through them, making it possible to reduce permeability effectively or even doing away with the drains altogether.

16. — Heavier loads and higher speeds can be allowed over old masonry bridges than those provided for when they were designed, provided a very careful check is made of the condition of the bridge; calculations for verifying the strength are not generally considered necessary.

Carrying out work to reinforce masonry bridges with the sole object of allowing heavy loads over them is consequently in practice exceptional.

17. — The work of repairing or strengthening the arches involves special precautions to avoid abnormal distribution of the stresses (anchoring irons, seams, jagging, centering).

Partial remaking of the arches is advantageous if it only affects a relatively restricted portion of the bridge and if the condition of the remainder of the arch, abutments and foundations is such that a long useful life can be expected from the repaired bridge.

18. — The organisation of the inspection and maintenance of bridges varies according to local circumstances; it is not possible to establish any general rules concerning the most rational maintenance methods for bridges.

Where the roads are adequate so that it is easy to get to the place of work by road, it is not advantageous for the railway to do the work itself, unless there is only a small amount of work to be done.

The geographical position and operating conditions on the railways may, on the other hand, alter the position and make it advantageous to carry out work of greater importance, or even oblige the railway to do all its own maintenance work without distinction.

19. — Those Administrations who themselves carry out maintenance work of some importance have specialised gangs, generally used exclusively on the maintenance of metal bridges.

20. — The materials needed for the repairs carried out by the bridge gangs are generally supplied from the stocks, stores or depots of the Administrations, whereas those needed for work carried out by contractors are supplied by the latter.

Several Administrations, however, prefer to supply in all cases the paint needed to repaint metal bridges.

[621 .143]

QUESTION 2.

Very long rails. Welding methods. Transport of long welded rails and necessary equipment for transporting, laying, fixing, ballast, tamping, etc.

Economic aspect of the question. Present tendencies,

by A. Jacops,

Chief-Engineer, Belgian National Railways

Special Reporter.

Two reporters were given the task of studying this question, which was the subject of the two following reports :

Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics, and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by F. Jackson (See *Bulletin* for March 1958, p. 379).

Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia), by A. Crespo Mocorrea (See *Bulletin* for August 1958, p. 1147).

It is remarkable to see how well the conclusions of the two reports agree; if there are divergencies of opinion concerning certain points of the subject dealt with, these appear in both groups of railways. Consequently, it will not be difficult to formulate the main principles which can be considered as now definitely proved.

First of all, it should be noted that after a period of hesitation, experimentation and prudent trials, long welded rails (L.W.R.) have definitely gained the favour of those railways which, after acquiring a veritable sheaf of theoretical studies and practical observations, have adopted this innovation without restriction; an innovation in fact which is without doubt the most important one as far as the permanent way is concerned that has been introduced since the origins of the railways.

The advantages obtained with L.W.R. are of three kinds :

1) the suppression of « shocks at the joints » which is a tax in the eyes of the public but which also leads, directly or indirectly, to premature damage to the ends of the rails and to the rolling stock — we have only to think of the numerous cracks and faults hidden under the fishplates;

2) an increase in the life of the rails on the main lines, estimated by some railways to be 25 %, or even 50 %;

3) savings in maintenance, which the least optimistic estimate to be in the neighbourhood of 15 %.

All the Railways, which are really interested in the matter, agree that the actual length of the rails, once it is more than 100 metres has in theory no limit. But there is far from being unanimity as to whether or not it should be adopted to make the rails of a given length approximately constant and connect them to-

gether with expansion devices; on the whole, opinions are equally divided on this point.

Those who favour an expansion device — mostly every 800 or 1 000 m (2600′ or 3 200′) — do so because they consider it may be necessary to destress the rail once or more frequently in its lifetime. Others are in favour of a normal fishplated joint, sometimes with rails limited at nearly the same length. But generally they think that, irrespective of the length, joints are only necessary where practical requirements such as insulation, switches, stations, etc., make it essential to have the continuous rail interrupted; in that case the joints are reinforced by a great number of anticreep devices.

A very special case seems to be that of the Soviet Union, where another new feature was introduced as an experiment, viz. a long welded rail « with automatic variation of length as a function of the temperature ». We lack sufficient details concerning this method of laying; but the large expansion allowance (878 mm = 2′ 10 5/8″), the fastening with curved edge base plates and the presence of a series of special « rectification appliances » anchored in the ground towards the middle of the L.W.R. lead us to think that this is a rail with practically absolute freedom to expand.

There are also differences of opinion — though these are less important — concerning the minimum radius of curves on which L.W.R. can be used. This seems to be due to the fact that the theory is not yet as sufficiently established in this particular case as in the case of straight sections because it depends essentially upon the characteristics attributed to the ballast, which are always very uncertain. If the technicians of L.W.R. generally agree upon the limit of 500 m (1 600′) radius for normal gauge track, on the contrary for narrow gauge track as it is much used in tropical countries, some wish to come down to the limit of 200 m (650′), while others consider there is danger to transgress that of 800 m (2 600′); the reporter is compelled to accept these divergencies without possibility of conciliating the points of view.

The cost of an expansion device must not be prohibitive for the use of L.W.R. In fact, according to the information collected, its cost compared with the length of track it occupies is on the average 2.5 and the cost of such an apparatus compared with the cost of one km of track amounts to approximately 1 %.

After feeling their way, the Railways have arrived, each by its own actual experience, at an almost unanimous opinion concerning the method of making L.W.R. : flash welding in the case of the longest lengths that can be dealt with in the shops, and joining up the joints *in situ* by various methods of welding. The order of succession to be adopted does not appear to be of special importance, but it is stressed that the work must be done when the temperature is close to the average for the locality.

Heating the rail in order to obtain this temperature by artificial means has been tried, but is not the general practice so far. The transport of long rails no longer gives rise to any problems.

As regards the kind of sleepers, there is a tendency to favour concrete, owing to its great weight, but there are no objections to wood or steel. As for the rail fastenings, there is a definite preference for those which give a really tight fastening; if this condition is not fulfilled, it appears that the addition of many anticreep devices to the ends of the rails may make up to a certain extent for any lack of rigidity in the assembly.

The sleepering and layer of ballast do not differ as a rule from the standard type adopted by the railways for their lines with much traffic. A wide bench is recommended (not exceeding 1 m or 3′3″) and if possible it should be slightly raised up or compacted.

As regards maintenance, all the Railways forbid the removal of the ballast from the track when the temperature exceeds the laying temperature to any great extent,

the latter being as close to the average as possible.

For the levelling of L.W.R., there is a tendency to prefer mechanical tamping to shovel packing, as this latter method is blamed for a tendency to favour transversal slipping of the track.

In this way, this synthesis of the opinions of the most representative Railways of the whole world makes it possible to conclude that the principle, formerly sacred, of the free expansion of rails has now been relegated to the domain of myths and that, provided certain perfectly normal elementary precautions are taken and certain perfections of secondary importance introduced, the L.W.R. can be used without restriction in the future, and will contribute fully to the renewed economic progress of the railway.

SUMMARIES.

Reducing the foregoing to the essential principles which are to be considered as established in the case of long welded rails, it is permissible to state :

1. The name and characteristics of « long welded rails » (L.W.R.) is given to continuous rails of at least 100 m (328′ 1″), whatever method be used to assemble them.

2. At the present time L.W.R. have undergone the test of eight years service in various climates, on lines with the heaviest and fastest traffic, without causing any difficulties. They are the best solution for obtaining at one and the same time smooth running, good conservation of the fixed installations and rolling stock, and a considerable reduction in maintenance costs.

3. From the theoretical point of view, there are no limits to the length of L.W.R., for this reason the determination of the actual continuous length the most suitable in practice is based on practical considerations. These have not been selected identically by the different Administrations.

Certain Railways fix this length simply according to operating requirements (isolating joints, track equipment, etc.), whereas others consider that a length of 800 to 1 000 m (2 600′ to 3 200′) should not be exceeded, for reasons of convenience.

There is an unanimous opinion that long rails should not be used on curves of small radius; but the limiting radius of curve varies considerably according to the Railways : in general, a radius of 500 m (1 600′) is considered the minimum admissible on standard gauge lines; in the case of lines of less than standard gauge it would appear that a higher limit, in the vicinity of 800 m (2 600′), is desirable for security.

4. The possible use of expansion devices depends upon the effective length of the rails : those Railways who limit the practical length of their rails to about one kilometre consider it generally necessary to use devices of this kind; on the other hand, those Railways who use long rails of various lengths, only limited by special circumstances, state that ordinary fishplating, completed by numerous anticreep devices, can be satisfactory.

5. All types of fastenings which assure close contact between the rail and the sleeper can be used with L.W.R. As far as elastic rail-spikes are concerned, experience of this device is still insufficient at the present time for a final judgement to be passed.

6. Although the weight of concrete sleepers makes them particularly suitable for lines laid with L.W.R., they can equally well be laid on wood or metal sleepers.

7. The ballast should consist of hard, sharp stones, of between 25 and 60 mm.

Wide ballast profiles should be used, the space between sleepers be well filled in and the bench heaped up in order to increase the transversal resistance of the track.

8. The method preferred for making L.W.R., both from the technical and economic points of view, is first of all to

flash weld in the shops the longest possible lengths of rail, transport these to their destination by suitable rakes, and weld them together on the line by the most suitable method. For this latter, the most widely used method is thermit welding. The above two methods of welding do not require any heat treatment after completion.

9. The temperature considered best for the final tightening up of the L.W.R. is a few degrees higher than the average between the extreme temperatures of the year. If this optimum temperature is not reached at the time the work is carried out, it is recommended to free the stresses and regulate again the length of the rails as soon as the desired conditions are realised. Heating the rails in order to obtain the desired laying temperature artificially has been tried sporadically, but is not the general practice.

10. The spacing of the sleepers and the method of putting new rails into service — in particular, speed restrictions on newly laid rails — are the same as those laid down for lines of similar category with relatively short rails.

11. The most suitable maintenance methods have not yet been finally perfected. But it has already been learnt that no work involving removal of the ballast from the line should be carried out when the temperature exceeds to any appreciable extent that at the time of laying or most recent adjustment. As regards the maintenance of the level, it is generally recommended to use mechanical tamping rather than shovel packing.

12. Administrations with a certain experience of L.W.R. are agreed that the safety of the traffic over L.W.R. is fully assured.

2nd SECTION. — Locomotives and rolling stock.

[625 .285]

QUESTION 3.

Design and improvement of railcars and multiple-unit diesel trains, as regards :

— traction power equipment (location and suspension of the engine, type of transmission);

— characteristics of the construction (body and bogies);

— weight reduction;

— sound-proofing, heating, ventilation, air conditioning (supply of power required, advantages and drawbacks);

— buffer and traction gear. Intercommunication,

by Dr.-Ing. G. A. GAEBLER,

Ministerialrat in der Hauptverwaltung der Deutschen Bundesbahn, Frankfurt am Main (West Germany).

Special Reporter.

I. INTRODUCTION.

The subject has been discussed in the following two reports :

Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Iran, Iraq, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics, the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories, West Germany, by Dr.-Ing. G. A. GAEBLER. (See « Bulletin » for February 1958, p. 145), and

Report (Austria, Belgium and Colonies, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Spain, Switzerland, Syria, Thailand, Turkey, Viet-Nam, and Yugoslavia), by A. S. CANAVEZES, Jr. (See « Bulletin » for April 1958, p. 499.)

Supplement to Report, by A. S. CANAVEZES, Jr. (See « Bulletin » for August 1958, p. 1261.)

The object of the present report is a synthesis of the two sectional reports and an elucidation of the recommendations deduced from their analysis.

The report is based in its essence on the replies furnished by the Railway Administrations listed below in response to a questionnaire compiled jointly by the two Reporters and forwarded by the General Secretary of the I.R.C.A. :

Austria, Belgium and Colonies, Denmark, Egypt, Finland, France and the French Union, Great Britain, Greece, India, Italy, Republic of Ireland, Japan, Luxemburg, Netherlands, New Zealand, Norway, Poland, Portugal and overseas territories, Spain, Sweden, Switzerland, Turkey, West Germany, and Yugoslavia.

The network of railway lines in service with these Administrations covers a total of about 259 000 km, on nearly half of which Diesel railcars and regular trains

hauled by Diesel locomotives are also in operation. An overall of 3 348 Diesel locomotives and 5 888 Diesel railcars is used by the Administrations, for the operation of which a total of roughly 554 000 metric tons of fuel was required in 1958, of which quantity a total of about 275 000 metric tons corresponds to the consumption of fuel by Diesel railcars alone (*).

Results achieved with this type of traction are analyzed below; it should be noted, however, that details supplied by several of the consulted Administrations had to be left out of consideration for the reason that they were incomplete and, if they had been included in the analysis, would have tended to distort the picture obtained on the basis of the calculated proportional values.

Results in operations during 1956.

Overall number of worked train-km	3 018 million km
— of which passenger trains	1 736 million km
— of which Diesel railcars and trains hauled by Diesel locomotives	379 million km
— of which Diesel railcars alone	344 million km
Overall number of metric ton-km	901 000 million metric ton-km
— of which passenger trains	226 000 million metric ton-km
— of which Diesel railcars and trains hauled by Diesel locomotives	25 000 million metric ton-km
— of which Diesel railcars alone	20 000 million metric ton-km
Number of traction vehicles operated with Diesel engines (locomotives and railcars)	9 236 units
— of which Diesel railcars alone	5 888 units

The above cited figures illustrate that in the areas served by the reporting Administrations, the transportation efforts contributed by Diesel railcars and expressed in the form of train-km constitute by far the largest share of train-km worked in Diesel traction, i.e., roughly 90 %. Likewise, the performance of Diesel railcars expressed in metric ton-km represents the largest share of the overall performance in Diesel traction, the ratio here being 76 %. Measured against the overall traction performance as applying to passenger trains, the kilometrage (abt. 20 % of the total) achieved with Diesel railcars is remarkable, whilst it is fairly modest (9 %), if the metric ton kilometrage is made the criterion. In conformity with the above quoted percentages, the inquiry, as relating to Diesel fuel consumption, showed that, although Diesel railcars are the lightest of all known traction systems and are preferably used in such services, their overall fuel consumption amounted to roughly one half of the total fuel consumption in Diesel traction. Moreover, the figures quoted above show that approximately two thirds of all Diesel operated rail vehicles are railcars.

The information derived from these inquiries is ample proof that a considerable portion of all tractive efforts in railway operations is attributable to the Diesel railcar.

The average daily kilometrage achieved per individual railcar — a figure that deserves closest scrutiny in evaluating the suitability and reliability of different railcar types and designs and also bears on the appraisal of engineering features to be embodied in new designs and, incidentally, makes the occasionally differing opinions of the Railway Administrations more easily understandable — varies rather considerably.

The above cited figures should, therefore, be taken as mere reference values,

(*) It was not specified in the reports furnished by the Administrations whether or not above figures of fuel consumption include fuel required for heating purposes.

quoted principally for the purpose of showing more clearly the proportions as they apply today.

II. FIELDS OF APPLICATION FOR RAILCARS.

(a) Hypotheses of railcar application.

Diesel railcars are a means of conveyance provided with their own traction power equipment, by which criterion their field of application is at once limited to transportation efforts embodying a lower paying load, and hence a smaller number of axles, than the ordinary engine-hauled train. It is this characteristic that accounts for the fact why railcars are used almost exclusively for the transportation of passengers and, specifically, almost invariably in services calling only for a small, or at best moderate, number of seats. In this particular field of application, railcars have a decided economic advantage over engine-hauled trains, especially if the engine is a steam locomotive. This superiority over engine-hauled trains diminishes with the ratio of increasing size and capacity of the units, due to the fact that the difference in expenditure for capital, maintenance, and energy supply also diminishes with the ratio of increase in size. At a certain point, the advantages of a traction vehicle (locomotive) separable from the vehicles used exclusively as a means of conveyance, assume a significant importance.

It may be fairly difficult to determine the dividing line of economic use between Diesel railcars and engine-hauled trains; it is likely to be dependent on transportation objectives, operating requirements, and the specific level of staff, fuel, and maintenance costs, and also the comparative investment values, and should be determined for each case separately.

Diesel railcars are generally most suitable in the following instances:

(i) Units of sets for the accommodation of very limited transportation requirements, involving a number of passengers no greater than that usually encountered on road buses with a trailer and light-weight trains, respectively.

(ii) Trains building up en route from several separate railcar services and/or branching out at one or more route junctions.

(iii) Multiple-unit sets with an essentially unchanging specific power to load ratio and an unvarying timing, but with a fluctuating load capacity — i.e. independent of length of set and, therefore, train load — at different hours of the day, as, for instance, in local and suburban services.

(iv) Light sets requiring a high specific power to load ratio for operating or topographical reasons (fast acceleration and grade climbing ability).

(v) Multiple-unit sets travelling at very high speed (as, for instance, streamlined sets) over considerable distances and especially on lines not electrified over the entire distance (rapid long-distance services).

(b) Scope of railcar application.

In conformity with their suitability as outlined above, railcars are used as follows:

(i) In branch line services.

(ii) In local suburban services in the vicinity of larger cities and transportation centres, in district traffic, and for cross-country services.

(iii) As connecting services from and to junctions between branch lines and main lines.

(iv) As connecting services from and to electrified main lines.

(v) In rapid long-distance services with limited seating accommodation.

(vi) In excursion and occasional services, party travel.

For the accommodation of traffic peaks of short duration, it is usually more advantageous to have recourse to engine-hauled trains than to increase the number of railcars or sets held in reserve to meet such

temporarily increased demand. However, it will probably be opportune to establish in each case separately which of the two solutions is the more favourable, coupled with an examination of the operational possibilities as relating to line capacity, especially on single-track lines.

(c) Railcar types and designs.

Railcar types and designs in use may be classified in three major groups with the following structural characteristics, in conformity with existing traffic requirements :

(i) *Small railcars :*

designed as twin-axle units, with a maximum speed of from 70 to 90 km/h, or

designed as four-axle units with bogies and a travelling speed of up to 110 km/h.

They are used without trailers or with one, but rarely with more than one, ordinary or control trailer.

The installed traction power varies between 120 and 300 B.H.P., available in one or two power units.

(ii) *Medium-sized railcars :*

invariably with bogies, for travelling speeds of up to 130 km/h;

customarily used with ordinary or control trailers.

Gangways are frequently provided between the motor unit and the control and ordinary trailer, respectively, but in some instances also between multiple-unit sets running combined.

The power output for the complete set ranges from 400 to 500 B.H.P., predominantly supplied by a single engine.

(iii) *Large railcars :*

invariably designed with bogies;

they are always operated jointly with one or more trailers and/or control trailer, with which they not infrequently form permanent sets.

The maximum speed attains 140 km/h, in isolated instances even 160 km/h.

The power output ranges anywhere from 500 to 1 100 B.H.P. per engine with its transmission, one or two such installations being used in the set.

Depending on the rate of available power, operating and line conditions, and travelling speed desired, a varying number of up to four ordinary or control trailers may be added per motor unit, thus providing very great flexibility and adaptability in number of accommodations available in the set.

III. IDEAS AND OPINIONS OF THE ADMINISTRATIONS CONCERNING THE DESIGN AND IMPROVEMENT OF RAILCARS.

(i) Number of engines.

The predominant practice is to use one engine only per railcar or set, for reasons of economy.

If engine designs are chosen from mass production of the motor vehicle industry, it is frequently necessary to employ two engines instead of one to attain the requisite power output which would otherwise be unobtainable with the relatively low power ratings of standard production. The decision to use two engines instead of one may also be influenced by the desire to refrain from adding to the number of engine types in use for relatively small numbers of vehicles in new classes, preferring in such cases the employment of engine designs of lower rating approved in other railcar designs. Another reason for the preference of two installations instead of one may be the availability of space for the installation of the traction equipment.

The theory has been advanced that the reliability of a design may be improved by dividing the overall power output between two installations. The consensus of opinion, however, seems to be to the effect that, in view of the present-day high standard of engineering development, one engine may be considered fully adequate.

(ii) Engine design.

Almost without exception, 4-stroke engines of medium and relatively high speed, respectively, are used, as their weight and reasonable space requirements offer definite benefits. The power output of engines of medium and higher ratings is frequently raised by supercharging, in which case the weight remains substantially the same, whilst the thermal strain stays within supportable limits.

The engineering development of supercharged and high speed 4-stroke engines counteracted the employment of 2-stroke engines in the domain of Diesel railcar construction.

(iii) Engine positioning in the railcar.

The following basic concepts are in existence :

(*a*) installation in the bogie;

(*b*) mounting under the body (underfloor installation);

(*c*) installation within the body.

The installation in the bogie, preferred during the earlier periods of design, lost much ground in favour of the underfloor mounting, due to the gain of useful space in the body permitted by this arrangement. Underfloor engines are used in large and medium size railcars with a power rating of up to 500 B.H.P., preferably with horizontal cylinders for the easier installation of this engine; for the higher engine ratings, this is considered indispensable.

The location of the traction power equipment in the body itself is chiefly encountered with engines of high rating.

Increased attention is being paid to an elastic suspension with adequate protection against vibration, dust, dirt, and noise. It is likewise increasingly considered good policy to make suitable arrangements for an easy engine servicing, an unimpeded complete exchange of the engine, the various other components of the traction power equipment, and miscellaneous accessories.

(iv) Engine cooling.

Water-cooled engines are predominantly used, protective compositions being frequently added to the coolant against the formation of scale and incrustations, corrosion and erosion in the cooling spaces of the engine, radiators, and heating equipment.

Where climatic conditions make it advisable, antifreeze solutions are also added to the coolant.

Air-cooled engines are relatively rare.

(v) Transmission.

(*a*) The mechanical transmission is preferably used with small and medium power ratings, occasionally in conjunction with hydraulic couplings;

(*b*) Hydraulic (hydrodynamic) transmissions for medium and high power ratings are in existence in a whole series of engineering concepts, ranging from the full converter with several circuits, or with a single circuit in conjunction with a multiple-speed mechanical gearbox, to combinations employing converters and hydraulic coupling circuits.
The application of hydrostatic transmission systems as a power transmitting component between the engine and the driving axles of Diesel railcars has not been reported up to now. Such systems, with a power rating of approximately 300 B.H.P., are, however, already in use in shunting engines employing the Diesel engine as the prime mover;

(*c*) The electric transmisison is used for medium and especially for high power ratings.

An interruption of the tractive effort of short duration occurs with mechanical and some hydraulic transmission systems. In the larger hydraulic and in all electric transmissions, this drawback is absent, either wholly or partially.

It is evident that in the position taken on the question as to which transmission system should be chosen in railcar construc-

tion, an indisputable *modification* of ideas has occurred in the period between the earliest railcar projects and the present day. Twenty years have elapsed since STROEBE reported to the International Railway Congress Association in June 1937 in Paris that, at that period, available experience with hydraulic transmission systems was yet inadequate and that, therefore, a final decision on their merit should be postponed; but that for the power range in excess of 200 B.H.P., the electric transmission was generally used, which had proved its reliability and was quite suitable to the application of remote control.

(vi) **Position of the transmission.**

The choice of position of the transmission is influenced by :

(*a*) the location of the Diesel engine, and

(*b*) the transmission system selected.

(vii) **Torque transmision to the axles.**

The transmission of power to the driving axles with mechanical and hydraulic transmission systems is preferably effected by using cardan shafts and axle drives, which in the majority of cases are constituted of bevel gears, but in the lower power range also of a worm drive.

Bevel gears are frequently spiral or helical toothed to reduce noise.

For the electric transmission, the Administrations consider nose suspension adequate for speeds of up to 125 km/h; in order to reduce the unsprung masses, however, a fully elastic suspension in conjunction with a tubular shaft is considered preferable, especially for the higher speeds.

(viii) **Driving position.**

The choice of driving position depends on whether or not the railcar is to be used alone as a self-contained unit or together with ordinary and control trailers or standard passenger carriages and possibly together with other motor units, respectively.

The general practice is to provide a driving position at both ends of the motor unit; the motor unit of a twin or muliple-unit set, on the other hand, always used jointly with trailers, often is equipped with a driving position at one end only, the other end being articulated to an ordinary or control trailer and provided with a gangway. One Administration reports an arrangement of the driving position high above the level of the roof, so that one driving position suffices for driving in either direction. Another Administration owns motor units without any driving position for use as traction components in multiple-unit sets.

(ix) **Control.**

By far the largest number of railcars reported are equipped with multiple or remote control, a prerequisite when operating under the following conditions :

(*a*) when two or more power units exist in the railcar or set;

(*b*) when railcars are equipped with more than one driving position;

(*c*) if a control trailer is included in the set;

(*d*) when several motor units are used jointly in multiple-unit sets.

There are, however, railcars in existence without remote control which, in the event that two or more such units are operated jointly in multiple-unit sets, require the attendance of a driver for each power unit, communication between the drivers being ensured by electric signals.

Supervisory equipment with gauges and indicators is frequently coupled with the control system to ensure the proper functioning of the plant.

(x) **Body.**

(a) *Superstructure.*

The body frame generally is erected from ordinary steel, with frequent use of cold-drawn or rolled profiles. Occasionally,

stampings are used, for instance, as cross members (spars). The combined steel and light alloy method of construction as well as light-weight construction is used in some instances. Steel or light alloy sheets are used for the exterior and interior skin, with attachment to the body frame by riveting, welding, or spot-welding. With the exception of a few experimental designs, stainless steel is not used in the areas served by the consulted Administrations, presumably because of its high cost and rather difficult working.

(b) *Sound-proofing and vibration absorption.*

In order to make travel in Diesel railcars more comfortable, increasing attention is being paid to noise and vibration elimination, which is generally conceded to be a factor of prime importance. Measures taken to this effect are chiefly concerned with the prevention of drumming, the insulation against noise (sound conducted through solids), and the absorption of sound by means of perforated sheets (sound propagated through the air). Particular efforts are made to avoid all openings in the car body or, if they are unavoidable, to seal and close them as carefully as possible.

Likewise, special attention is paid to the insulation of passenger accommodation against noise and vibrations produced by the engine and its auxiliaries, in particular, where they are located in the immediate vicinity of passenger accommodation. The inevitable additional load resulting from such measures is tolerated with good grace. The desirable criterion for the maximum of permissible noise within the car body is stated to range from 65 to 90 phons.

(c) *Heating.*

The following heating systems are used :

(1) hot water heating;

(2) hot air heating;

(3) steam heating;

(4) electric heating.

Where the first two systems cited are in application, the waste heat of the engine coolant is generally made available for heating purposes. If a separate boiler exists with hot water heating systems, a junction is made between this circuit and the engine cooling circuit to permit preheating and the conservation of heat of the engine coolant.

Steam heating systems are used in Diesel railcars in the event that they are jointly operated with standard passenger carriages equipped with a steam heating system. Such instances are rare.

Hot air heating systems are more responsive to regulation than hot water heating systems. Moreover, they are very useful during the warm season in that they can be employed to replace the used air in the car interior by fresh air drawn in from the outside.

Where hot water or hot air heating systems are used, each unit in a set is equipped with its own and fully independent heating installation.

Electric heating is applied in vehicles of a high standard of comfort, cars that are generally also equipped with an air-conditioning plant.

Heating systems in which the waste heat of the exhaust gases is utilized directly are no longer used, chiefly due to the fact that their proper function is determined by the engine load, but presumably also because obnoxious fumes may seep into the car interior if there is a leak in the line, where direct heat extraction from the waste gases is used, and to avoid pollution and corrosion.

(d) *Ventilation.*

For the ventilation of railcars not equipped with an air-conditioning plant, static suction ventilators on the roof, electric fans, and drop windows are provided, the windows in the most simple designs of railcars occasionally being represented by mere laterally opening ventilating flaps. If a hot air heating system is applied, this is additionally utilized for ventilating purposes, as was stated earlier.

The installation of an air-conditioning plant will increase the load and also the purchase price of railcars, for which reason, in countries with a temperate climate, such installations are considered justifiable only in vehicles of a high standard of travelling comfort. In vehicles of this category, double pane fixed windows are provided which cannot be opened.

The energy required for the operation of an air-conditioning plant and its heating and cooling is generally supplied by a current generating plant equipped with its own Diesel engine, instead of having its power supplied by the car axles. This makes the installation independent of the car battery, aside from the fact that a non-varying voltage is thus ensured, irrespective of temporary operating conditions of the vehicle.

(e) *Buffer and traction gear.*

The standard draw and buffing gear is preferred for railcars, frequently, however, of a lighter construction than is ordinarily used. This enables them to be operated jointly with standard passenger carriages and goods wagons, which might be a decided advantage on branch lines with a modest volume of goods traffic. On the other hand, railcars with automatic centre couplings are also in existence, sometimes embodying an automatic coupling of the air lines and multiple control circuits. Such vehicles can be operated with similarly equipped rolling stock only. The application of such equipment offers advantages to railcar services where a rapid coupling and uncoupling of units is required while en route.

(f) *Gangways.*

The application of gangways is generally recommended where the nature of the service is able to support the additional charge. Gangways are not considered absolutely indispensable in strictly local services. On the other hand, they may be expedient in services in which the occupancy of trains undergoes frequent changes, as for instance on suburban lines, where they are valuable in that they permit passengers to pass from overcrowded cars into less crowded units of the set, thus permitting shorter stops at en route stations and promoting train staff economy.

For the circulation of passengers in the train, ordinary gangways or gangways with bellows are used. The use of the former is usually restricted to railway personnel, whilst the latter, especially if the vehicles are employed in rapid services, occasionally include a flexible envelope between individual units at the level of the side walls to reduce wind resistance, particularly at high speed.

(xi) Light-weight construction.

It is the well-considered opinion of the Railway Administrations that weight saving in the construction of Diesel railcars and their trailers and control trailers is important and necessary. So far as railcars for rapid long-distance services are concerned, it is believed that the possibilities of additional load reductions are limited by considerations of the passenger's comfort.

The vital importance of weight saving in Diesel railcar construction is emphasized for the reason that their prime movers, in contrast with those in alternate traction systems, do not allow an overload. It is not only a demand imperatively imposed by economic considerations, among which may be cited : lower purchase price, lower operating cost (reduced fuel consumption), and less wear and tear (on the running gear and brakes), that makes conservatism in the calculation of the required power output advisable, but also the ever-present engineering difficulties in the construction of railcars, due to the lack of space for the accommodation of the engine and its auxiliary equipment.

One of the criteria to which power output and load must conform is the ratio :

$$\frac{\text{power output}}{\text{weight to be moved}} = \frac{\text{B.H.P.}}{\text{tons}}.$$

This ratio varies, in conformity with the original purpose of the railcar and the particular service conditions, and ranges from approximately 5 to 10 B.P.H. per ton.

The efforts of the Administrations to reduce the load extend to *all* components, i.e., the car body, interior furnishings, mechanical equipment and running gear, special attention being paid to the weight reduction of all non-suspended components (axles, axle drives, nose-suspended drives, etc.).

Structurally, weight savings are effected by the application of light steel construction, with extensive use of welding, of combined steel and light alloy construction, and the use of light metals and their alloys, and plastics.

The limits of light-weight construction are determined by the amount of additional expenditures due to design and increased building costs (investment). In a similar manner, questions of the passenger's safety have a vital bearing on these considerations.

(xii) Running gear.

The running gear, i.e., carrying axles as well as driving axles, is, in the majority of cases, arranged in bogies. Railcars of the most simple design only, usually conceived as twin-axle vehicles, are equipped with rigid axles.

Both for the primary and secondary suspension, steel springs, i.e., leaf and coil springs, and torsion bars, are employed, the use of the coil springs being increasingly recommended as a means to improve running stability. Air spring systems are experimentally employed by several Administrations.

Extensive use is made of hydraulic shock-absorbers to dampen spring movements. Self-damping springs, consisting either of rubber or made of rubber and steel, are also recommended, especially for the secondary suspension.

The axles are guided by the axle-box cases and the slide-bars in the horn-guides. It is endeavoured to eliminate the play both in the longitudinal and the transverse axes by connecting the axle-box case to the bogie by guide bars.

In order to prevent the propagation of pitch vibrations from the bogie to the car body, the pivot is placed at a considerably lower level in the bogie, bringing it as near the level of the axles as possible.

IV. CONCLUSIONS.

On the basis of the information supplied by the Railway Administrations consulted it may be stated in conclusion that, even though a slight diversity of opinions and ideas exists on certain details, there is basic agreement in that their unanimous objective of using the Diesel railcar is greater economy (lower operating costs), on the one hand, and an improvement and acceleration of services and increase of travelling amenity, on the other.

With due regard to the ideas and opinions of the individual Administrations, conditioned as they inevitably are by the diversity of structure and conditions as they exist in the several countries in the national economy, industry, and transportation, the views and experiences indicated by the Administrations as relating to the development and improvement of Diesel railcars permit the following generally valid conclusions to be drawn from these reports :

(*a*) The reporting Administrations consider the employment of Diesel railcars in passenger operations opportune, because this type of transportation shows the following favourable characteristics :

- (i) flexibility, permitting high utility and rapid turn-round;
- (ii) high average speed due to rapid acceleration, resulting from the generally favourable power to load ratio;
- (iii) adaptability to existing transportation needs, with the ability to maintain time-table requirements irrespective of length of train (where the design permits coupling and remote control of several units);

(iv) economy, to the extent that their use is limited to the performance of specific suitable services;

(*b*) The economy of Diesel railcar operations depends on the following factors :
(i) nature of traffic demands;
(ii) volume of transportation requirements;
(iii) frequency of services needed.
Diesel railcars offer the greatest economy when used for moderate loads, for which reason they are used almost exclusively in passenger transportation, specifically in services with a modest demand of accommodation, and in shuttle service;

(*c*) Within the limits set by the power output available in the motor unit, the number of seats may be adapted to existing traffic demands by the addition of ordinary or control trailers. Where suitable provisions have been made, even standard passenger coaches or goods wagons may be coupled to the motor unit. The composition of multiple-unit sets built up from several motor units presents no difficulty, if there are wide fluctuations in traffic demands at different periods of the day, week, or season;

(*d*) The facility of coupling several units into a set, in conjunction with the possibility of providing remote control, renders the Diesel railcar a particularly suitable instrument in services which are operated jointly as multiple-unit sets for only part of their total run, i.e., where units join the set en route or branch off at different junctions for different destinations (through carriage problem).

SUMMARIES.

The above considerations and ideas on the opportunity of using Diesel railcars in railway operations permit the formulation of the following conclusions relative to their design and improvement :

1. The number of types of different designs of Diesel railcars should be limited as far as practicable. The economy of railcar operations improves with the number of completely identical units in service in the area of the Administration.

2. Whilst it may be necessary, for reasons of traffic requirements, to provide various types of interior arrangements and equipment, all efforts should be made to maintain uniformity of design, as relating to the most important components subject to wear and tear (as, for instance, traction power equipment, auxiliary machinery, running gear, brakes, buffing and draw gear, doors, windows, etc.).

3. The installation of a *single* traction power unit (Diesel engine plus its transmission) in each motor unit is the more economical method, if suitable equipment with the necessary power output is available on the market.

The installation of two separate units, for reasons of operating reliability, is no longer necessary, in view of the present high standard of design and manufacturing technique.

A subdivision of the total power output in *two* separate units may be opportune for the following reasons :

(*a*) limitation of types of mechanical equipment in use;

(*b*) to permit the installation of two smaller underfloor engines instead of a single large unit which, due to its size, would have to be mounted in the car body, in order to profit from the gain of space (for passenger accommodation) obtained by this solution;

(*c*) to permit the utilization of engines and/or transmissions available from mass production of the motor vehicle industry, thus benefiting by the relatively low first cost and maintenance charges for spare parts.

A division of the power unit in two may also become inevitable, if a high power requirement makes the installation of a single unit impracticable.

4. High speed Diesel engines are, as a

rule, preferable for use in Diesel railcars for the following reasons :

(*a*) dimensions are smaller, thus requiring less space for a given power rating and facilitating the installation;

(*b*) the engine has less weight, and component parts are correspondingly lighter and, consequently, are generally less expensive.

5. Supercharging of Diesel engines (provided the design is suitable), and in particular of 4-stroke engines of medium and relatively high rating, may be recommended for the reason that a notable increase in power — up to 50 % — may be obtained at the cost of a relatively modest increase in load and thermal strain.

6. It is generally preferable to use 4-stroke engines, because the benefits derived from supercharging are more effective with this engine design.

7. The underfloor arrangement of the tractive power equipment should be used for small to medium ratings, as it provides more space for the payload in the car body.

Accessibility of the underfloor power unit is of great importance, but this can be arranged without difficulties.

The tractive power equipment of medium to high rating may be installed either in the bogie or in the car body. Installation in the bogie offers the advantage of facilitating the exchange of the entire power unit, inclusive of its bogie, whilst the installation in the car body insures a better accessibility of the power unit even in operation.

The protection of the power unit against bad weather conditions and dirt, as well as a more efficient noise insulation are more easily realized with the installation of the engine in the car body.

8. The following transmission systems are suitable :

(*a*) mechanical or hydraulic transmissions, or combinations of the two systems, for low power ratings;

(*b*) mechanical or hydraulic transmissions for medium power ratings; the superiority of the hydraulic transmission rises in proportion with the increase in power output; the electric transmission becomes feasible as the power rating approaches the upper range of this category;

(*c*) hydraulic or electric transmissions exclusively for high power ratings.

9. The position of the power unit (Diesel engine with its transmission) in the railcar is influenced by :

(*a*) type and location of the Diesel engine, and

(*b*) choice of transmission system.

Both the mechanical and hydraulic transmissions require a more restricted layout of engine, transmission, and driving axles.

The electric transmission on the other hand, allows greater freedom in the arrangement of the power unit with its generator and the axle drives (traction motors).

10. In order to ensure the proper functioning of the power unit in operation and to enable suitable measures to be taken in the event of a breakdown, the installation of suitable supervisory instruments to be watched by the driver or of automatic control apparatus is to be recommended, covering for instance, the engine coolant temperature, engine coolant reserve, oil pressure, and oil temperature.

Automatic control has the advantage that it :

(*a*) is continuous so that it becomes immediately operative in case of failure, and

(*b*) leaves the driver free for the performance of his other duties as they relate to train operation, etc.

Its drawback is a somewhat higher expenditure for first cost and maintenance.

Traction power installations of high rating, which are necessarily expensive, warrant the installation of automatic control apparatus.

Alarm apparatus or indicators of a more simple design should prove adequate for

less costly power equipment operating under less exacting conditions.

11. Water-cooled Diesel engines make protective measure of the cooling system advisable against :

(*a*) corrosion and erosion;

(*b*) scale formation and incrustation;

(*c*) freezing during the cold season.

12. For hydraulic transmissions with coupling characteristics and for mechanical transmissions, the inclusion of a protective device for the engine against overspeeding through torque exerted by the driving axles is to be recommended.

13. The driving position(s) of Diesel railcars and their control trailers, if any, and of multiple-unit sets, respectively, should be arranged in such a manner that :

(*a*) a good visibility is ensured;

(*b*) the travelling direction may be reversed without turning the vehicle.

These conditions are most satisfactorily fulfilled with the driving position(s) arranged at the end of the vehicle.

But the provision of a single driving position at a high enough level either at one of the ends or at about the centre of the railcar also ensures a satisfactory visibility, even if a trailer is running ahead of the motor unit, provided the vehicles are not excessively long.

High-level end-driving positions can afford greater safety to the driving staff, especially in such cases where part of the power unit is built into the car body immediately in front of the driving position at the level at which an impact with possible obstacles on the track might occur.

Care should be taken in the design of the driving position to ensure that the driver is protected from eye strain due to the inclusion in his line of vision of the track passing directly beneath his eyes.

The provision of a driving position at each end of the set suffices for twin or multiple-unit sets, the components of which are never used separately.

14. In railcars used under simplified conditions, with a single power unit and not required to run jointly with a control trailer or other motor units, direct mechanical control of the power unit and its auxiliary is possible and adequate. This type of control is reliable and economical to purchase and maintain, because of its simple construction.

On the other hand, railcars to be used jointly with a control trailer or other motor units should be equipped with remote control, unless the cost of the staff needed to attend two or more power units represents a smaller money outlay than the building, operation, and maintenance of multiple control equipment.

In designing for a strictly limited combination of power units, a relatively simple and inexpensive multiple control may be provided.

When the traffic requirements involve the use of a larger number of power units, operated together by a single driver, a multiple control system in conjunction with fully automatic control of power units, as described in item 10, is necessary.

15. One of the determining factors of economic operation of Diesel railcars is the structural weight, as it influences :

(*a*) the determination of required power output;

(*b*) the fuel consumption;

(*c*) the extent of wear and tear (in particular of the running gear components and brakes), and consequently, the extent of repair costs;

(*d*) the purchase price.

This makes it advisable to limit the weight to an economically tolerable minimum value.

Efforts to effect weight savings should extend to all components of the railcars and their trailers and control trailers, whereever this can be achieved without impairing the safety of passengers, reducing travelling comfort to any noticeable extent or incurring liability of heavy maintenance and renewal costs.

A reasonable additional charge incurred by increased expenditures for design and materials as a consequence of an intensified light-weight construction may be tolerated to a certain extent, in view of the expected savings.

Construction methods recommended to effect weight savings are :

(*a*) light-weight construction in steel with extensive welding;

(*b*) combined steel and light alloy construction;

(*c*) application of light metals and their alloys and plastics;

(*d*) utilization of light-weight mechanical equipment and other fittings.

16. At the designing stage of Diesel railcars, the following measures suitable to enhance travelling comfort should receive careful attention :

(a) *Insulation against noise and vibrations* involving, so far as the car body is concerned :

— prevention of drumming;
— absorption of noise;
— insulation against noise including the avoidance of openings admitting noise in the car body. When openings are unavoidable, they should be carefully sealed to prevent noise from reaching passenger accommodation

and relating to the engine and its auxiliaries :

— insulation against noise and vibrations produced by the traction power equipment.

A certain increase of the weight of the vehicle caused by insulation requirements is justified.

(b) *Heating.* — The following systems may be recommended for the heating of railcars, trailers, and control trailers :

— hot air heating;
— hot water heating;
— steam heating;
— electric heating.

Where a hot air or hot water heating system is used in the railcar itself, it is advisable, for the sake of power economy, to make use of the waste heat of the engine coolant. The additional insertion of a heat generator in the heating circuit is to be recommended, permitting pre-heating of the engine coolant and passenger accommodation before going on duty; these systems also allow keeping both the engine and passenger accommodation warm, if there are operating interruptions of long duration.

Steam heating systems should be applied only if railcars are to be operated jointly with standard passenger carriages equipped with steam heating.

The additional expense of electric heating is supportable where Diesel-sets are required with a high standard of comfort.

Heating systems which make direct use of the heat of waste gases, cannot be recommended for the disadvantages inherent in such systems.

It is especially important that the heating system used provides for a satisfactory regulation of heat and is quickly responsive to regulator settings.

(c) *Ventilation.* — The ventilation of railcars used under ordinary conditions should be effected by opening windows and the provision of static suction ventilators on the roof; for services with a higher standard of comfort, the installation of electric fans may be envisaged.

Hot air heating systems should be designed in combination with the ventilation of the car interior.

It is self-evident that, except for countries with an unusually hot climate and subject to dust conditions, and apart from vehicles offering a rather high standard of comfort, the provision of an air-conditioning plant is prohibitive on account of its high cost and additional weight. Where such an installation is included, it is recommended that it should have its energy supply provided by a separate generator, driven by an auxiliary Diesel engine.

(d) *Gangways.* — If the kind of service provided supports the additional expenditure, it is advisable to provide gangways

for the passengers between the individual railcars in a set, designed as :

— gangway floor plates, normally for the use of railway staff only;

— gangways with bellows of various designs as a protection for passengers against weather conditions and for safety and other reasons where a certain degree of comfort applies to the vehicles.

(e) *Running gear.* — The running gear should be designed to ensure an optimum of riding stability, even with an average state of maintenance of the permanent way.

With the exception of the most simple designs, bogies should be used in the running gear.

As an additional means to improve riding stability, one or more of the following devices should receive careful attention :

— coil springs or torsion bars, practically without self-damping, for the secondary and primary suspension, together with hydraulic shock-absorbers; special care must be taken to counterbalance the natural frequency of vibration of the various suspension systems;

— self-damping springs of rubber or combined designs of steel and rubber;

— guide bars between axle-boxes and bogie frames, instead of the ordinary axle-boxes sliding in the horn guides, to eliminate the play in the longitudinal and transverse axes and to avoid wear and tear;

— locating the bogie pivot at the lowest practicable level.

Air spring systems, as well as any other design of springs with a gas or vapour chamber, have thus far seen little use in the design of railway vehicles, so that experience with this type of suspension is still lacking. However, it may be opportune to study the applicability of such systems, especially in view of the fact that the tendency is unmistakably in the direction of light-weight construction. With this type of construction, the value of the inherent possibility of these systems to ensure an automatic adaptation of characteristics to widely fluctuating loading conditions is obvious. These new systems may show the way towards genuine improvements; several experimental vehicles are already in use.

17. *Buffer and traction gear.*

If the possibility has to be envisaged that passenger coaches and goods wagons equipped with the ordinary buffing and draw gear may have to be hauled by railcars, the latter must be equipped similarly. In this event, it suffices, however, to employ a lighter design of such buffer and traction gear, as the loads to be hauled will be light.

Where no such possibility has to be taken into consideration, automatic centre couplings may be used as standard equipment for railcars and their trailers. They are especially advantageous in services requiring quick coupling and uncoupling of units en route.

The automatic centre coupling may be designed to ensure automatic coupling of the brake air line and multiple control circuits.

[**621** .335]

QUESTION 4.

Comparative study of the periodical maintenance and repair of electric locomotives, in particular as regards :

- the wear of the tyres (influence of the wheel diameter, the axle-load, the speed, the type of bogies and eventually undulatory wear of the rails, etc.);
- the maintenance of traction motors and their transmission (flash at the collectors and methods of coping with it, use of roller bearings for the suspension of the motors and the hollow shafts, etc.);
- lubricants used (classical and such new types as bisulphide of molybdenum);
- wear of the friction strips of the pantographs.
- Kind of work and periodicity.
- Organisation of the maintenance and influence of common user (banalisation) of the locomotives.
- Prime cost in relation to the type of equipment and the age of the engines,

by K. J. Cook,

Chief Mechanical and Electrical Engineer, Eastern and North Eastern Regions. British Railways.

Special Reporter.

Question 4 has been covered by the following reports :

a) Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Union of Soviet Socialist Republics, Viet-Nam and Yugoslavia), by M. Viani. (See « Bulletin » for July 1958, p. 1025);

b) Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by K. J. Cook (See « Bulletin » for March 1958, p. 499);

c) Supplement to Report, by K. J. Cook (See « Bulletin » for August 1958, p. 1279).

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I. GENERAL DATA.

Of the 95 Administrations to whom the Questionnaire was sent 24 replied. It should be emphasised that the report deals with *electric locomotives.* A number of Administrations have no electrified railways and of those Administrations which have partly electrified, some only operate passenger services with multiple unit stock. This leaves 26 which operate electric locomotives and the reporters are very grateful that 24 Administrations replied in great detail to the rather lengthy questionnaire and have furnished very valuable information.

The year 1955, relating to which information was requested, is not completely static except for a very small number of electrifications as in many cases electrified lines had not been in full operation for much time or further extensions were in hand. Nevertheless, a great deal of information has been gathered.

The total electrified route mileage reported is approximately 41 000 (65 000 km). There are some small Administrations which are completely electrified and Holland appears to work 80 % of its gross t-km by electric traction. In general, however, electrification extends to less than 10 % of the total route mileage of those railways which are partly electrified. Details of systems and electrified mileages were given in the above-mentioned reports respectively drawn up by Mr. VIANI and the author. (See *Table 1*.)

D.C. systems vary at 600, 750, 1 500 and 3 000 V the first and last covering the biggest mileages but the 3 000 V is being rapidly extended on one large system. The number of locomotives which form the subject of this special report is approximately 4 700 and many details of these were shown in *Table 3* of Mr. VIANI's report and in *Table 2* in the Supplement to the author's report.

The average annual mileage per locomotive varies considerably being influenced greatly by the length and character of the routes and traffic. It appears that the general average mileage for passenger locomotives is 70 000 - 80 000 (112 000 - 128 000 km) and for freight traffic about 50 000 (80 000 km). These figures in some cases appear lower than might have been expected. Four Administrations do, however, report the following high annual mileages of a single class of locomotive in each Administration :

Deutsche Bundesb.	231 000 km (144 000 miles)
Austrian Railways.	230 000 km (143 000 miles)
S.N.C.F.	304 000 km (190 000 miles)
Swiss Federal Railways	230 000 km (143 000 miles)

Brakes. The standard method of braking appears to be by cast iron brakeblocks applied to the tyres by compressed air, supplemented in many cases by regenerative or rheostatic braking or by a combination of both. Details of this are to be found in *Table 4* of Mr. VIANI's report and in *Table 3* in the Supplement to Mr. COOK's report. There is no indication of the use of non-metallic brakeblocks on electric locomotives.

Speeds. The maximum speeds for passenger locomotives reported is 160 km/h (100 miles per hour) but 120 to 144 km/h (75 m.p.h. to 90 m.p.h.) is a more general range and in most cases the designed maximum speed of locomotives is above the permissible speed for the lines. The general running speeds of passenger trains are 80 to 105 km/h (50 to 65 m.p.h.) and of freight trains 45 to 60 km/h (30 to 40 m.p.h.). The maximum and usual running speeds reported by Administrations are detailed in *Table 5* (Mr. VIANI's report) and in *Table 4* (Mr. COOK's report).

II. WEAR OF RAILS AND TYRES.

The general practice on electric locomotives is to use wheel centres with tyres, but in some cases monoblock or solid wheels with tyre profiles are used, but such applications are on guiding wheels. Germany, however, uses cast steel wheels on account of special profile and driving gear. Experience acquired by this Administration with the use of cast steel wheels is generally good apart from a few cracks due to high loads.

Rails are generally of medium manganese steel, manganese ranging from 0.60 % to 1.20 % with carbon 0.50 % to 0.82 %, maximum sulphur permitted varies from 0.06 % down to 0.04 % and phosphorus 0.05 % down to 0.04 %. As heavier rail sections are used there appears to be a tendency to increase carbon and manganese contents. Tensile strength varies from 65 tons/sq. in. to 35 tons/sq. in. with elongations of 8 % to 14 % but more generally in the higher range of tensile strength.

Tyre steel has a very similar composition to that of the heavier rails, maximum carbon being slightly lower but manganese and silicon approximately the same, maximum sulphur and phosphorus 0.05 % tensile strength about 60 tons/sq. in. with elongation 10 %.

Table 6 of Mr. VIANI's report and *Table 5* of the Supplement of the author's report gives particulars of steel specified for rails and tyres.

There is no indication that the composition of rail steel has been modified on account of electric locomotives but the remarks above regarding heavier sections of rails may be relevant.

It appears, therefore, in general that a state of equilibrium has been reached in which the hardness of rails and tyres are equal and probably this is desirable in order to reduce adverse effects of one upon the other.

Reports indicate that the useful life of rails under electric traction is less than with steam traction but a quantitative comparison is difficult as there is generally an increased service under electrification. The reduced life may be of the order of 20 %-50 %. One Administration reports that this reduction applies to rails on curves but not on straight. However, some of the Administrations supplied the following data :

Italy (State Railways).

The average life of a rail with electric traction is 20 years, whereas with steam traction it is 25 years. There is no doubt that this reduction in the useful life of a rail with electric traction is mainly due to the increase in the speed and the load both of the locomotive itself and that of the trains hauled when changing from one type of traction to the other.

U.S.S.R. Railways (Russia).

State that the lateral wear of the rail is five times greater with electric traction than with steam traction, and its vertical wear 30 % greater with the former than with the latter.

Austrian Railways.

Estimate at some 20 % the reduction in the life of rails on electrified lines.

South African Railways report a useful life of rails on straight track of 25-40 years with electric or steam traction but that on curves the wear is 30 % greater with electric traction.

Japan states that the useful life of rail under electric traction is 50 % to 70 % of that for steam traction and quotes the following figures :

	Passage tonnage (Millions per annum)		*Average amount of wear (mm per annum)*	
	Steam	Electric	Steam	Electric
Straight track	27	29	0.8	1.2
Curved track	26	27	4.0	5.8

The *Bundesbahn* estimates vertical wear of the rail at 0.05 mm per million tons.

The limiting forms of wear vary as between batter at rail ends, side cutting, topwear, the appearance of flaws and cracks and in some cases corrugation which may occur chiefly on sharp curves. South Africa reports that the mean depth of the worst corrugations is of the order of 2.5 mm (0.1 in.); when the depth reaches 4.7 mm (3/16 in.) the rails are removed. The wavelength of the corrugations is 60-75 cm (24-30 in.).

Some Administrations lay down limits of wear of rails. For example, the *Netherlands Railways* fix the minimum thickness of rail head at 20 mm (0.79 in.) and the maximum angle of inclination of the lateral

wearing surface compared with the vertical arcs of the section of rail at 32°.

The *Swedish State Railways* find that they cannot lay down precise limits but work according to the following principles :

Side cutting.

The running edge of the rail head must not be worn so much that the distance « A » in sketch begins to decrease *(fig. 1).*

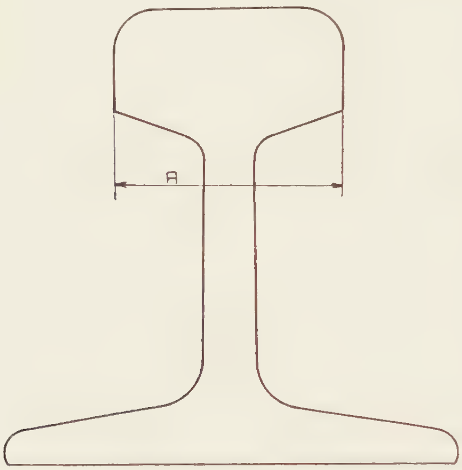

Fig. 1.

Spreading of the rail head.

The spreading must not be so extensive that there is a derailment risk for trolleys with double flanged tyres (used, for example, for the normal inspections of the track).

Wear of rail head.

The vertical wear must not exceed 4 mm and rail ends must not be hammered down too much.

It is clear from the information obtained that geographical circumstances vary very greatly between Administrations and consequently the mileages which can be run before tyres require reprofiling vary from 26 000 to 250 000.

The *D.B.* fixes for its types E-04, E-18 and E-16 locomotives a mileage of 250 000 (400 000 km) which is the highest of any given. For the type E-44, this mileage falls to 110 000 (175 000 km).

In *Italy,* the mileages are given as a function of the type of locomotive and they vary from 100 000 to 200 000 (165 000 km to 325 000 km).

South Africa quotes 80 000 to 120 000 miles but on type (3 E) with position interchange 200 000.

Japan gives mileages of 26 100 for locomotives used on curved or gradient sections to 37 300 for passenger locomotives mainly used on level line sections.

Swedish State Railways state that the mileage varies between 93 000 miles and 250 000 miles whilst *Great Britain* gives a figure of 70 000 miles for passenger service and 57 000 for freight working.

The factors affecting this are chiefly :

(1) passenger or freight service;
(2) curvatures;
(3) gradients;
(4) length of haul between stops;
(5) slipping, which will be influenced particularly by (3) and (4).

No. (2) will largely govern the amount of wear into flanges and No. (5) will be the greatest factor causing tread wear.

Various combinations of these factors will produce a great number of limiting mileages. There appears to be definite indication that flange wear on curves can be considerably reduced by track oilers.

Tyre wear in some cases necessitates the locomotive being taken out of service between normal heavy repairs but in other cases it is corrected whilst other work is being carried out. The provision of track oilers has in some cases enabled tyre profiling and other repairs to be brought together.

There is much variation in the limits of wear permitted and these can also be sub-

divided into stage limits and final limits. The stage limits can be regarded as the wear permitted before the profile must be reformed as distinct from the final limit which will govern the minimum thickness at which a tyre can be permitted to remain in service.

On stage limits, running surface or tread wear allowed varies from 1/4″ (6.3 mm) to 3/8″ (9.5 mm) sometimes governed by a maximum depth of flange of 1 1/2″ (38 mm). Flange wear permitted varies from 1/4″ to 1/2″ (6.3 mm to 12.7 mm) the general point at which this is measured being 9/16″ (14.3 mm) from the top of the flange, the minimum thickness at this point being 3/4″ (19 mm). In only two specified limits is there any mention of the final angle of the worn face of flange; it must not become less than 17° and the tip of this face must not approach nearer to the top of the flange than 3 mm (1/8″) when this angle is reached. This is as specified by Japan and details are shown in *figure 2*.

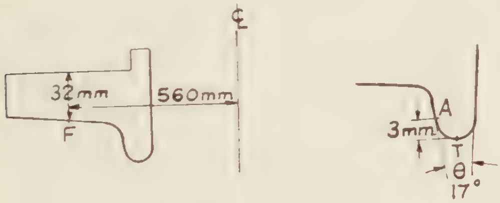

Fig. 2.

The final limit, in conjunction with flange limits quoted above, occurs when the minimum thickness of tyre in the centre of the tread is reached and the lowest figure specified for this is 32 mm (1.28″). On British Railways the minimum thickness is 1 1/2″ (38 mm) as indicated in *figure 3*.

The maximum flange wear generally occurs on the outer wheels of a locomotive, be they guiding or driving wheels. The amounts of wear permitted are mentioned in *Table 8* (Mr. VIANI's report) and in *Table 6* (Supplement to the author's report).

It has not been shown that the rate of wear is affected by wheel diameter relative to the nominal or new diameter.

No general agreement is indicated to limitations of axle-loading relative to wheel diameter. There are indications that

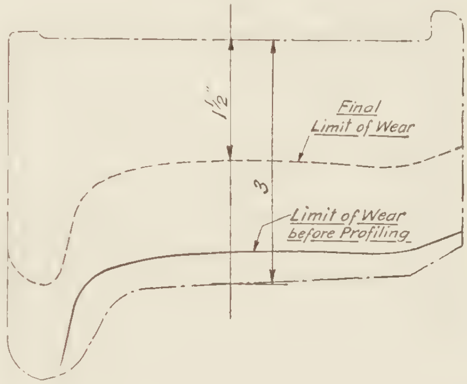

Fig. 3.

thought is being given to this and some Administrations have in mind a figure of 4.5 to 5 tons (axle load) per foot of diameter. Such figures, however, may place onerous restrictions on locomotive design.

Most of the Administrations do not fix any predetermined value for the ratio $\frac{P}{D}$ when designing new electric locomotives. However the S.N.C.F. makes the reservation, that though it does not impose such a value, the figures shown on the table on next page have been fixed as the maximum for this ratio in the case of the modern locomotives.

The Netherlands Railways stipulate $P < 0.016\ D$ in tons and metres and the Jugoslavian Railways $\frac{P}{D} = \frac{20\ t}{1\,250\ m}$.

General opinion appears to favour articulated bogies and it is claimed that reduced flange wear results from this provided that there is freedom of movement of the inner headstocks of the bogies and

	Metric tons and metres	*English tons and feet*
CC express, with completely suspended motors	14	4.3
BB mixed, with nose suspended motors	16	4.9
CC freight, with semi-suspended motors	19	5.7

that there is a centring device on the coupling.

Certain Administrations, such as the Italian State Railways, the Swiss Federal Railways, the Austrian Railways, and the R.E.N.F.E. report that there is a definite relation between the wear of the running surface and the flange and the type of connection between bogies. In fact the last Administration has observed considerably reduced wear of the flanges on the outer axles of certain types of the C-C locomotives when there is an elastic connection between the inner headstocks. In the same way, the S.N.C.F. reports that this influence begins to be appreciable when the recall force is of the order of 10 tons.

It is clear that there is a strong opinion on the economic value of lubrication to reduce both flange wear and side cutting of rails. Lubrication of flange of rail will also benefit the flange of the tyre as the lubricant is carried round a curve by the passage of wheels.

These lubricators are mainly used on curves of small radius, for example 300 to 500 m (15-25 chains), and sometimes by points; however the Belgian Railways also use rail lubricators on curves of 1 200 m (60 chains), in general siting them at the beginning of the curve. One Administration only (the Algerian Railways) site the lubricators in question at the spot where the superelevation reaches 40 mm (1.57″).

The S.N.C.B. uses a single type, consisting of a cylindrical reservoir fixed outside the rail containing grease graphited under pressure. This escapes over the lateral inside face of the railhead under the action of two pistons worked as each tyre passes over them. The grease used has been perfected by the firm of Caltex.

The Algerian Railways use automatic rail lubricators, P. & M. type. The lubricant used is 50 G graphited grease (Esso-Standard).

The Italian State Railways use two types of lubricators, which are now under trial, in the form of equipment fastened to the rails or placed on the locomotives. The grease is a mixture of calcareous soap and mineral oil, saponifiable oil and graphite, in the following proportions :

Saponifiable oil	not more than 3 %
Lime soap	10 to 14 %
Acids	not more than 0.2 %
Water	not more than 2 %
Graphite	12 to 14 %
Ash	not more than 12 %
Penetration by ASTM method of grease used at 25°C :	305/335
Ubbelohde drip point	above 85°

The Netherlands Railways use the English P. & M. type.

The S.N.C.F. generally lubricates the rails by means of mobile lubricators fitted on the locomotives. However, in certain cases, for example on isolated curves of lines with fairly heavy traffic, P. & M. type lubricators are used (pumps driven by small fingers worked by the passage of the wheel which lubricate the rail) fitted outside the track; the hollow spindles form a sort of tube which brings the oil used as lubricant over the inside surface of railhead. Although these lubricators are placed at the entry to curves, they must be carefully

sited if good results are to be obtained. If there are a relatively large number of curves, S.N.C.F. considers it more economical to use lubricators fitted on the engines.

The Rhaetian Railway, in addition to greasing the flanges by lubricators fitted on the locomotives, also has the inside surface of the railhead greased occasionally by the platelayers equipped with a manual lubricator mounted on a small truck. The lubricant used is old oil, or a special grease (Aseol) with a graphite base.

As regards the economic advantages of using rail lubricators all the Administrations which have used them report considerable reduction in the lateral wear of the rail, and some, like the S.N.C.B. and Algerian Railways, report an increase in the life of the rail of 100 % and 50 % respectively.

The S.N.C.F. calculates that on certain twisting lines, the mileage before the locomotive tyres have to be returned can be increased threefold or even fourfold.

Use of flange lubricators.

There are a great many types of flange lubricators; mention may be made of those known under the names of *Lubrovia, Bertschmann Limonfluhme, Friedmann,* and those consisting of electro-graphited carbon rods, oil pulverisators by means of ejectors worked by compressed air, etc.

All the Administrations agree in affirming that the use of flange lubricators gives positive economic advantages, without being able to estimate these in any precise fashion.

The principle on which the *Lubrovia* lubricators are based makes it possible to use them either on the wheels or on the rail. This type, mainly used by the S.N.C.F. has the advantage, when it is lubricating the rail, that its use is good both for the motor stock and hauled stock.

The effect of method of suspension of traction motors on rail or tyre wear cannot be assessed as most Administrations have to date only nose-suspended motors. One Administration reports that this method causes more tyre wear than frame mounted motors.

As most of the modern electric locomotives are of the so-called « universal » type, i.e. designed for use on both passenger and freight trains, thus assuring a mixed service, the Administrations find it impossible to determine whether the kind of service worked, from the point of view of the speed by express trains, stopping and freight trains has any influence upon the wear of the tyres.

The S.N.C.F. state that there is a certain relation between the wear of the tyres and the kind of service. For two comparable series of locomotives, each used on a different service, the wear of the tyres is about 10 % less on locomotives working fast services than those used for the mixed services. British Railways can partially segregate the services and indicate a figure of 18 %.

When tyre profiling is necessary wheels are removed from locomotive and tyres are returned in heavy duty wheel lathe using high speed or tungsten carbide roughing tools or buttons, finishing with profile former tools.

The kilometres run between tyre turnings as reported by the Administrations are indicated in the reports. (See *Table 7* in each case.)

Release of the locomotive when requiring tyre turning only may be greatly accelerated by changing bogies. Congo Railways do not regard tyre turning as a cause for immobilisation of the locomotives as they have a sufficient number of spare bogies. British Railways also follow this practice and carry out a change of bogies within a few hours.

Very few Administrations adopt the practice of building up worn tyre flanges by the deposition of weld metal but the following reports may be quoted :

One Administration, the Algerian Railways, uses the Union Molt system with a welding current of 70 V, 650 A.

The Italian State Railways begin by heating the surface which is to be built up to

250 or 300° using D.C. and basic electrodes, taking care that cooling takes place as slowly as possible, thanks to an asbestos protective plate.

R.E.N.F.E. merely builds up the flanges, seeing that these undergo the most wear, owing to the many small radius curves its locomotives have to run through, and does not machine after depositing the metal.

As for the economic advantages obtained, it appears that there is an appreciable saving in the tyre material, the period between overhauls being increased by 30 to 50 % according to the information supplied respectively by the U.S.S.R. and C.F.F. Railways.

There are no reports of the use on electric locomotives of tyre profiling machines for reforming tyres in situ under locomotives. British Railways are, however, installing a profile milling machine with the object of keeping wheels under a locomotive until they must be taken out for renewal of tyres.

III. MAINTENANCE OF TRACTION MOTORS.

There is general uniformity in certain features of traction motors reported, viz :

D.C. motors 4 poles with 4 auxiliary poles;

Roller bearings on armature shafts;

Axle-hung bearings — bronze shell with white metal lining — one Administration reports roller bearings on all locomotives;

Lubrication to axle bearings, oil with pads, waste packing or wicks.

Brush holders follow a uniform pattern adjustable only for radial gap but brushes vary between solid and divided with and without flexible connections.

Arcing horns are being increasingly used to prevent damage to commutators by flashovers.

Weight of traction motors varies from 1.7 tons up to nearly 5 tons. One Administration reports weight as less than 1 ton — this is a small line and may be for light duty only. The transmission of power from motors to axles is predominately unilateral but there are also bilateral gears. Involute, straight and helical teeth are employed. Gear cases are split about the shaft axes and are principally of sheet steel but some cast steel cases are used. Seals to prevent oil creepage to the armature are important.

Table 10 of Mr. VIANI's report and *Table 8* in the Supplement to my report give details of the traction motors used by the various Administrations.

Systematic maintenance of traction motors is carried out under three headings :

(1) Periodic inspections;

(2) intermediate overhauls;

(3) general overhauls.

It follows a fairly uniform pattern as shown by the table on the following page.

A few Administrations make a daily inspection but when this takes place it is a superficial inspection carried out by inspector or driver.

The periodic inspection, as far as the traction motors are concerned, chiefly relates to brushes and commutators, the former particularly to ascertain that there is sufficient length remaining to enable brushes to function satisfactorily until the next inspection and that spring pressure is correct. These periodic inspections are planned at intervals by different Administrations ranging from 14 to 45 days which correspond to mileages of 3 000-10 000 (4 800-16 000 km).

At the general overhauls the motors are disconnected, the bearings, induction coils and armature cleaned; a general check is made of the lubrication, the commutator rectified on the lathe if necessary, the brush-holder checked and rectified, and finally, if considered necessary, complete or partial rewinding. In this case, it is considered essential to test the motor on no load.

The frequency with which the commutators are turned varies according to whether this is based on years in service or

Administration	*Period between inspection of brushes, etc*	*Period between overhauls*	*Mileage between overhauls Km*	*Remarks*
South Africa R. & H.	21 days			
Japanese Govt. Rlys.	25 days	4 years	75 000 — 298 000	Intermediate repair annually
U.S.A.	Monthly		480 000 — 640 000	Also daily inspection
Swedish State Rlys.	Twice Monthly		200 000 — 600 000	
Svenska Jarnvagar	Monthly		80 000 — 100 000	Inspection
London Transport	Monthly	3 years	160 000	
British Railways	35 days	5 years	400 000 — 640 000	
Indian Govt. Rlys.	45 days		240 000 — 400 000	

on mileage run. In the first case, the frequency varies between 1 and 3 years; in the second, between 200 000 and 600 000 km (125 000 and 375 000 miles); exceptionally it is as much as 1 200 000 km (750 000 miles) on the C.F.F.

The S.N.C.F. fix as limits 400 000 to 600 000 km (250 000-375 000 miles) with D.C. and stipulate that this limit should be above 600 000 in the case of A.C. single phase, industrial frequency motors.

At the intermediate repair it is not usual to dismantle so much nor to turn the commutators unless inspection indicates an abnormal condition. In general, it is not intended that the full repair should be necessary before a large mileage has been run over a number of years, but it would appear that in some cases this is actually done more frequently.

The Administrations were asked if, before turning the commutators, the wear of the latter was measured. In general, the wear is noted as far as traces left upon the commutator by the rubbing of the brush is concerned. Their depth determines in many cases whether turning is necessary. In other cases, the ovality of the commutator is checked, and it is precisely the measurement of this latter which is taken as the basis in determining the advisability of turning during the periodic repairs, as is the case for example on the F.S. The rest of the Administrations merely note the wear.

In the case of motors recently put into service, the S.N.C.F. check these measurements systematically and prepare a small graph on which to record the ovality of the commutator, which serves as basis for the comparative study of the way it stands up in service.

One of the immobilisations of locomotives being due to need to turn the tyres, such immobilisations are used to carry out when necessary certain of the above mentioned operations on the traction motors, but in general there is no coincidence between the work of inspecting and repairing the motors and the turning of the tyres, which usually is necessary after a smaller mileage than that after which the general repair of the motors is necessary. In many cases such immobilisations of the locomotive are used solely to blow out the armature with compressed air.

It is very rare that damage to the commutator makes it necessary to take the motor out of service. However, in order to reduce this risk to the minimum, the commutator should be cleaned during the periodic overhauls, thus avoiding deposits of dust as well as when examining and improving the functioning of the brush-holder and checking that the commutator and armature are co-axial.

Insulation is generally to Class *B* but there is a trend towards improved insulation by using inorganic materials such as glass fibre. In the construction and repairing of traction motors, so far the classic types of insulations have been used. Only the D.B. has used insulation of the modern type in conformity with its technical development to reduce possible damage. In the same way the S.N.C.F. is now studying the possibility of using them on old motors in order to prolong their life.

Brush pressure is set when motors are assembled and it is not expected that great variation will occur, but if hand testing casts any doubt upon the pressure being exerted a test by spring balance is made.

Table 12 of Mr. VIANI'S report and *Table 9* of the Supplement to my own report give comprehensive details of dimensions of brushes and brush-holders used by the reporting Administrations.

Commutators are not expected to require returning other than at heavy repairs which are at mileages above, say minimum of 300 000 miles and then the cut should not be more than 0.010″. In one case, however, it is reported that it is done at three years and mileage of 100 000 but this is on a suburban passenger service with very short distances between stops.

Motor design in most cases allows of the armature shaft being withdrawn without dismantling the armature but it does not appear to be so designed primarily for the purpose of crack detection in the shaft.

In sequence with the increasing use of ultrasonic methods for axle examination, these are being extended to armature shafts supplementary to visual and magnaflux methods.

This is done at major overhauls but it appears from replies that the incidence of cracks in these shafts is practically unknown. Armature bearings also are only dismantled for examination or replacement at the heavy overhauls.

As previously mentioned, roller bearings are not used for motor suspension and, therefore, no cracking of axles has arisen from the use of them.

In order to reduce the frequency of operations of replacing the armature bearings, it is usually stipulated that high quality metal shall be used for the linings (80 % tin), that the lining shall be done by centrifugal force followed by polishing « in line » and glazing of the bearing surfaces, as well as machining the journals of the shafts and carefully adjusting the bearings in the body and cap, together with the use of special lubricants.

The tolerances adopted for the axial play of the bearings vary from 0.3 to 1.3 mm (0.012″ to 0.051″), and in the case of the lateral play, from 0.6 to 3 mm (0.023″ to 0.120″) as a rule. Finally, as the method of centering, simultaneous centering and machining of the bearing in relation to the cap and inductor is stipulated, as well as synchronised tightening up of the fastening bolts.

Bearings of axle or hollow shaft.

In the case of completely suspended motors with a hollow shaft it is the current practice to use bronze or steel lined with white metal (antifriction) bearings.

The composition of the lining metal varies between the following limits :

tin	78 to 83 %
antimony	13 to 15 %
copper	6 to 9 %

On certain railways the lining metal contains 66.5 to 69.5 % of lead and the proportion of tin is reduced to 14 %.

As for the play and wear allowed, these vary between the following limits :

radial play of the hollow shaft	0.3 to 1.3 mm (0.012″ to 0.051″)
axial play of the hollow shaft	1 to 3 mm (0.040″ to 0.120″)

These limits are established, as is only logical, as a function of the type of locomotive.

Lateral displacement of nose suspended motors.

In order to avoid shocks due to lateral displacement of the motor against the hubs of the wheel and to keep the gears as central as possible, the Administrations have used special arrangements, such as:

— connecting rod from the motor to the framework of the vehicle;

— suitable design of the axles;

— stop rings;

— brakes on the axis of the motor;

— conical cambered roller bearings in the case of oblique teeth.

In the fitting of pinions to armature shafts there are opposing practices in providing or not providing keys, but fitting of keys preponderates. It is fairly universal practice to provide taper seats for the pinions (taper of 1 in 10 is quoted in one case); to require bearing on the shaft of 80 % of the area and then to shrink on at a temperature of 95° C. to 105° C. either by soaking the pinion in boiling water or in an oven. The pinion is then tapped into position or assembled in a press and where a locking nut is provided this is assembled and locked in position as quickly as possible.

Opinion is also divided upon the question of whether it is necessary to keep pinions and gear wheels matched, i.e. if it is necessary to change a motor without changing the wheel and axle to transfer the old pinion to the replaced motor. Some organisations say no and one, which used to carry out this practice, has abandoned it on the ground that it is not worth the expense and also from the fact that one spur wheel lasts the life of two pinions. Some Administrations, however, think it very necessary. It is unusual for traction motors to be changed at other than main Works except in cases of emergency.

Flashovers on electric locomotives appear to be rare and when they do occur are generally caused by frost or snow, contamination by smoke from steam locomotives, dust, or by lightning. There are, however, varying devices to assist in current collection, viz:

use of two pantographs or one pantograph with two pans to reduce current collection per pan or pantograph;

two or more collecting strips on each pan;

auxiliary springs to help pan follow the wire;

air vane on high speed locomotives to keep pan level;

use of maximum overload and over voltage relays, as well as the use of quick acting circuit breakers to limit peak currents;

fitting of arrestors on locomotives to limit surges caused by lightning;

instructions to train crews to limit current and fine division of resistances to assist in this;

separate wheel slip indicators are fitted in a few cases but crews are also taught to deduce this from armature field meters;

provision of arcing horns so that when flashover does occur, current goes to earth and does not flash across and damage commutator.

Most of the Administrations have no statistics to indicate the frequency of this flash as a function of the mileage, separating as we asked them to do, cases in which it was due to the brushes being earthed from those where it took place between the commutator segments.

The only data supplied on this point were the following:

Algerian Railways: one flash per 165 494 km (103 434 miles) (28 months);

out of a total of 14 flashes, the division was: 4 due to brushes earthing, 10 between commutator segments.

C.F.F. :

- 0.3 to 3.2 per 100 000 km (62 500 miles) for brushes earthing;
- 0.3 to 5.8 per 100 000 km (62 500 miles) between commutator segments, according to the series of locomotives;

Austrian Federal Railways state that on the series 1 020 freight locomotives one flash occurred every 50 000 to 70 000 km (31 250 miles to 43 750 miles) when they were used to haul express trains.

Snow or rain ingress to traction motors causes trouble in some regions and this is countered by fitting screens. In other cases where the air is drawn from the body of the locomotive, the louvres and filters provide sufficient protection.

IV. LUBRICANTS.

Lubrication of armature bearings is by grease or high viscosity mineral oil. The greases used are generally composed of refined mineral oil and soap or calcium.

There appears to be a little more variation in the lubricant for the axle or hollow shaft bearings of traction motors, from greases composed of refined mineral oil and soap, high viscosity mineral oil to a light machine oil.

Table 13 of Mr. VIANI's report and *Table 10* of the Supplement to the author's report include the characteristics of the oils and greases used at different times of the year by the Administrations which change the lubricants according to seasonal temperatures.

There are some like the C.F.F. who only change the oil used in the S.L.M. universal drive, using machine oil in winter and cylinder oil in summer and the Swedish State Railways who change only the oil in axleboxes with plain bearings from normal wagon axlebox oil in summer to locomotive axlebox oil in winter. This Administration and the North Milan Company make the change completely at fixed dates whereas in most other reports it is effected by applying the appropriate grade of lubricant as additions are needed for topping up.

Enquiry was made as to whether any railways use any new lubricants or additions such as molybdenum sulphide, but there has not been any indication that it is used nor of lithium based greases.

Heavy gear compounds are used for gears and this is applied by very orthodox methods of grease guns or pumps. The S.N.C.F. tried out the use of polythene bags by which to add measured amounts of grease but it appears that they have given it up, on account of its excessive cost.

Enquiry was made to ascertain whether gear lubricant found its way into the suspension bearings of the motors and caused difficulties. Most Administrations replied in the negative, except the S.N.C.B., N.S.M., S.N.C.F., Jugoslavia and British Railways who have found traces of this. The provision of seals, maintaining lightness of joints in gear cases and by eliminating differences in pressure, either by making equalising conduits or facilitating communication with the atmosphere indicate the steps taken to prevent it.

V. WEAR OF THE PANTOGRAPH STRIPS.

It appears that considerable attention has been paid to the selection of the most suitable material for pantograph strips. *Table 14* of Mr. VIANI's report and *Table 11* of the Supplement to my report show some of the replies from the different Administrations concerning the friction strips of pantographs. This shows the material of which these strips are made, their number and size, method of fixing to the pans, precautions taken to avoid arcing between the strip and the armature and the maximum wear allowed in the strips.

As will be seen from this table most of the Administrations continue to use the classic materials for these strips, such as steel, copper, aluminium and carbon, to

exclude the collection of current by vitrified metal.

There are, however, some exceptions. Japanese Government Railways have used copper and also carbon strips but discarded copper because it wore too heavily and carbon as it limited current collection, in favour of a sintered metal composed of copper, tin, iron, nickel and graphite.

The F.S. have also tried a sintered material in order to avoid the dangerous rise in temperature which occurs on the contact line when carbon is used.

The North Milan Railways have tried various copper alloys, and have come to the conclusion that the most suitable has the following composition :

copper	65 %
lead	30 %
tin	4.6 %
nickel	0.4 %

Finally the U.S.S.R. Railways are now making tests of replacing the strip of copper by graphited steel.

Compound strips of copper and steel side by side have also been used with some improvement but up to the present copper strip either hard drawn or with some alloy such as cadmium, aluminium or steel has been most favoured, but there does appear to be a tendency to adopt carbon principally because it is applied thicker and can wear further and in the expectation that it will cause less wear on the contact wire.

The railroads in the U.S.A. are experimenting with carbon impregnated with babbitt metal.

Where the standard metal strips of copper, aluminium, steel, etc., are used they are about 1 1/2″ (37 mm) wide and 1/4″ thick (6.25 mm) secured by screws from the underside of the pan. Carbon is mounted on a sheet steel base and clamped by side pressure to a fixing on the pan.

In one design of pan two copper strips running the length of the pan along the outer edges are augmented by two additional strips 18″ long in the centre of the pan. The contact length is, therefore, 4″ at the most used portion of the pan. The outer edges of the long strips are provided with a radius.

The pantographs are lubricated by placing the lubricant in the grooves between the strips. Graphite grease is the general lubricant used — it is efficient and can easily and quickly be applied. At inspection grease is added if required and if the old grease has hardened it is scraped away and replaced by fresh.

Some Administrations, such as the S.N.C.F., add 5 % petroleum to the graphited grease in winter. The U.S.S.R. Railways have tried for some years apparently with success using solid graphite (65 % graphite and 35 % resin). The British Railways have applied molybdenum bi-sulphide as an anti-scuffing medium which has reduced wear of the strips.

The lubricant is generally applied by hand, with a spatula, by the motorman when beginning work, or by the depot staff whilst inspecting various parts of the locomotive. Only the solid graphite tested by the U.S.S.R. is applied in a melted state to the pan which is heated after it has been removed from the pantograph and is then replaced in its proper position.

The life of the strips is reported as ranging between 16 000 to 48 000 km and varying factors influence the rate of wear. Increased wear is attributable to wintry atmospheric conditions, high speeds, contamination of the contact wire by steam locomotives where these operate and by dust. There are, however, contradictory reports on the effect of wet weather.

In some cases it is possible to count upon an average of 60 000 to 80 000 km (37 500 to 50 000 miles). There are some Administrations where renewal takes place much more frequently, for example the F.S. and R.E.N.F.E. where it takes place every 8 000 to 12 000 km (5 000 to 7 500 miles). On the other hand other Administrations, such as the Lower Congo, renew them every 100 000 km (62 500 miles), which means approximately 8 months in service.

Finally, the information obtained from the C.F.F. shows that using aluminium strips, renewal is necessary in winter every 15 000 to 25 000 km (9 375 to 15 625 miles), whilst with carbon strips it is necessary after about 50 000 to 90 000 km (31 250 to 56 250 miles).

Pans are examined for wear at short and long period inspections and changed when the limit of wear is reached. General practice is to exchange pans but in one case strips are renewed whilst pans are left in position. Between these periodical examinations of strips, complete pantographs are only examined superficially from the ground. Pressure is tested at each long period inspection.

As regards the influence of the type of service, the S.N.C.F. and S.N.C.B. agree in stating that wear is greater in the case of stopping services and mixed services than with express locomotives (up to 30 % greater in France). On the other hand the D.B. stated exactly the contrary, i.e. wear is 30 % greater on the fast vehicles than on the slow, perhaps the type and tension of the current used have an influence upon these results.

From the replies received to our questionnaire, we were not able to get any exact figures concerning the influence upon the wear of the friction strips of other operating factors such as the pressure of the pantograph on the wire, the amount of stagger, the intensity of the current picked up, the relative hardness of the metal used for the contact wire and the material used for the strip, etc. The majority of Administrations contented themselves with indicating :

(*a*) that the wear increases with the pressure of the pantograph on the wire;

(*b*) polygonal stagger of the contact line favours the maintenance of the strips and distribution of the lubricant;

(*c*) wear increases with the intensity of the current picked up, but the influence of this factor is less than that of the above two;

(*d*) the hardness of the metal used for the contact wire and for the pantograph strips should be more or less similar, to avoid rapid wear of one or the other.

There are two components of strip wear, one mechanical caused by friction and the other electrical caused by the passing of current. The former may be greater at high speed but the electrical component may be prominent at points where heavy trains are starting or pulling at slow speeds. The sum total may, therefore, vary according to differing proportions of the two kinds of wear.

Upward pressure of pantograph is generally specified to be within the range of 16-20 lbs. (7.27 kg to 9.09 kg).

The S.N.C.B. controls the pressure on the contact wire which should be 7.5 kg ± 15 % (16.5 lbs. ± 15 %) by checking the lifting up of the pantograph with a weight of 6.375 kg (14 lbs.) and its descent with a weight of 8.625 kg (19 lbs.) between 4.8 and 6.25 m (15′ 9″ and 20′ 6″) above the rail.

At the maintenance depot of one line, the pantograph shop is on the first floor, above the roof level of locomotives and a hand operated platform is arranged to be able to be traversed out from the shop above the locomotive to facilitate changing either pan or, if necessary, complete pantograph. On other lines, mobile platforms are provided to facilitate access to the pantographs.

Formation of ice on pans is not found to be a trouble but it is considered that the grease used as a lubricant also acts as a preventative.

VI. ORGANISATION OF MAINTENANCE AND PERIODICITY.

The maintenance of electric locomotives falls into a general pattern but the actual figures of time and mileage between repairs vary very greatly according to characteristics of each railway system.

It is exceptional for a daily examination to be made other than that carried out by train crews on taking over or giving up a locomotive (see Section VII). The maintenance systems provide for (*a*) inspec-

Administration	Inspection		Intermediate overhaul		General overhaul		Remarks
	Short period	Long period					
	Days	Days	Years	Mileage	Years	Mileage	
South Africa R. & H.	1	21	—	120 000	—	750 000	
	—	21	—	200 000	—	Not yet fixed	
Japanese Govt. Rly.	—	25	1	10 000	4	46 000	
	—	25	1	47 000	4	186 000	
U.S.A.	1	30	—	—	—	300 000	Freight
	1	30	—	—	—	400 000	Passenger
Swedish State Rly.	—	—	—	—	—	125 000	
	—	—	—	—	—	250 000	
Svenska Jarnvagar	—	14	—	—	—	50 000	
British Railways	7	35	—	70 000	5	250 000	Freight
	7	35	—	100 000	5	400 000	Passenger
Indian Govt. Rly.	—	6 000 miles	—	50 000	—	150 000	
	—	8 000 miles	—	125 000	—	250 000	

tions, (*b*) general overhauls and (*c*) an intermediate or lighter repair between (*a*) and (*b*) necessitated by attention to tyres or bogie. As the variations in periods and mileages between these are so great, it is thought desirable to give a table showing the ranges of these. (See above.)

At some multiples of the long period inspections the work becomes more extensive.

The general overhaul includes a complete strip down of mechanical and electrical gear and renovation or repair of all components. A number of intermediate repairs will be carried out between general overhauls chiefly depending upon tyre wear.

S.N.C.B. has supplied very fully details of the work carried out at different stages of maintenance and these are quoted in full as follows :

A. *Small maintenance.*

1. Electrical part. — Checking the starting gear, the motors, pantographs and roof insulator.
2. Mechanical part. — Replacing the brake shoes, inspecting the bogie to find any cracks, and examining the fastenings and condition of the parts. Compressed air and vacuum equipment. Greasing the joints, cleaning.

B. *Big maintenance.*

In addition to the small maintenance jobs, the following are carried out.

1. Electrical part. — Complete inspection of the equipment and summary cleaning. Checking and tightening up the connections, contacts and blow-out de-

vices, automatic and manual starting, dead man's handle and gauges.

2. Mechanical part. — The same work as during small maintenance.

C. *Intermediate overhaul.*

1. Electrical part. — Measuring the L.T. and H.T. insulation. Greasing the pantograph cylinders. Cleaning the traction motors and rectifying the commutator; painting and varnishing insulating parts. Thorough cleaning and measuring the starting resistances and equipment. Checking the contacts, blowout devices, relays, tension regulators (L.P.) and cut-outs, including verification of the pressure, if necessary, and replacement if necessary. Rectification of the collectors of the auxiliaries. All the big maintenance jobs.

2. Body. — Cleaning and painting the roof, interior, corridors and driving compartment. Checking the connections between bogies, the buffing and drawgear, the brake rigging. Cleaning the brake cylinders. Thorough check of the tightness of the compressed air pipes and all taps, cocks and fittings.

3. Bogies. — Turning the wheels. Checking, cleaning and replacing if necessary the axle bearings and traction motor bearings. Renewing the joints of the bearings and gearcases. Dismantling the brake rigging and replacing worn rings and pivots. Detailed examination of the suspension and connections between bogies and body.

D. *General overhaul.*

1. Electrical part. — Complete overhaul including dismantling the pantographs, traction motors and auxiliary groups, quick-acting circuit breakers, servo-motors with cam shafts, certain H.T. contacts and checking the H.T. and L.T. electric conduits.

2. Body. — Painted throughout, inside and out. Repairing all cocks, taps and fittings and the brake gear. Repairing the doors and floor.

3. Bogies. — Completely dismantled. Detailed check of the gears. Replacing the seals of the bearings and gearbox, as well as the pivots and bushes.

This general overhaul includes all the operations carried out in the former overhauls, so that the locomotives at the end are in the same condition as when they were first put into service.

The time found necessary to carry out repairs varies considerably depending upon the extent to which spare parts are exchanged. This greatly facilitates the intermediate repairs, particularly when spare bogies are utilised.

A short period inspection requires 1 to 2 hours, long period 6 to 10 hours, intermediate repairs vary from 1 day for change of bogie to 10 days and general repair from 11 to 30 days, the longest time occurring when the stage is reached at which insulation of cables, etc., is breaking down and complete re-wiring is necessary.

Much attention has been given to endeavours to increase the length of period between heavy overhauls, principal items being :

Reduction of tyre wear by provision of flange or rail lubrication;

Improved lubrication of axle bearings by felt oilers and substitution of roller for plain bearings;

Improvement of grade of insulation;

Analysis of condition of parts dismantled to ascertain if periods between dismantling can be extended;

Quick exchange of individual components in connection with this analysis and reducing the number of components dismantled.

All maintenance work is carried out at Works or Depots other than short daily inspections where these are instituted. All intermediate and general overhauls are carried out at the Main Works at the periods quoted.

The limiting factors which influence

inspection and shopping periods are chiefly pantograph strip wear, brake block wear and adjustment between inspections and tyre and commutator condition for longer period repairs. Statutory requirements also influence short period examinations in some instances.

The repair liability is carefully planned by each Administration which can deduce, from anticipated total mileage expected to be run during each year and the known mileage which each class of locomotive can run between repairs, the number of repairs of various categories which will be required during a year in order to maintain the stock in serviceable condition. The possibility of extending mileage between heavy repairs is always in view. The short period inspections can be controlled on a purely time basis and there appear to be fairly common systems of central shopping controls which regulate the allocation of locomotives to Works for repairs.

All Administrations report that the changing of bogies is carried out at Main Works and it is important that the repairs to the bogies removed are put in hand quickly to maintain availability.

The direction in which management has moved in endeavours to shorten time of locomotives under repair are in the provision and maintenance of spare parts and interchangeable assemblies, analysis of method of carrying out repairs and of the wear which takes place in order to eliminate or reduce the wear and consequently the need to repair or change and, as tyre wear is one of the major influences, attention is being directed towards the use of machines for reprofiling tyres which are in position under the locomotives.

VII. ORGANISATION OF THE SERVICE AND EFFECTS OF COMMON USER OF LOCOMOTIVES.

It is almost universally reported to be the practice to employ electric locomotives in a pool in common user. In only two reports is there any divergence from this practice. F.S. in the case of passenger service and R.E.N.F.E. allocate each locomotive to a certain number of drivers, between one and three according to the service. These Administrations state that this system has the advantage of the engine crew having in this way a much more thorough knowledge of their locomotives, which reduces damage, and is perfectly compatible with a good user of the motor stock. Nevertheless they are introducing common user of all their locomotives as the length of the electrified lines increases.

Other than these, the system of common user is so universal that it can be said that there is no real alternative. It follows that there is changing of drivers either en route on long distance trains or at turnround points where journeys are short. Change of crew may be necessary on account of a driver having completed his hours of work or in order to give him a break for food or personal needs.

On long distance trains the point of change may be settled by the need and cost of learning the road and the extent to which it may be considered prudent to confine crews to areas.

All this arises from the capability of electric locomotives for continuous working and the need to utilise the expensive machines fully and to keep to the minimum the number of locomotives and hence the capital cost.

In general the locomotives only go back to the depots when it is necessary to carry out some maintenance work on them. There are however, some cases in which the locomotives go back to the depots, either for the daily inspection, or to put them under cover in order to save them from the weather, or to change the engine crews, or for reasons of a social nature (dormitories and canteens).

When the locomotive is immobilised because it is not needed or because maintenance work has to be carried out on it, it frequently happens that it is stabled in the station, or on a siding, rather than in the depot. These sidings are often equipped with inspection pits for the con-

venience of inspection and any small repairs that may be required.

Stabling in the stations or sidings may have the advantage of convenience for the staff, and allows the locomotive to be put into work very quickly. On the other hand, it has drawbacks in the case of very low temperatures accompanied by frost snow, etc.

If temperatures are not extremely low it need not be detrimental but it brings out the need for adequate heating in the cabs in order to bring up the temperature therein to a reasonable degree in a short time. On British Railways, although not subject to the extremes of temperature encountered in some countries, it is nevertheless important. These freight locomotives are immobilised at the week-end, when freight and mineral traffic falls off, in sidings attached to trains ready to start away from midnight on Sunday onwards. Unlike the steam locomotive it replaces there is no firebox and the internal temperature may approximate to the external. It is essential to heat up the cab quickly in order to make driving conditions satisfactory. It has been found necessary to augment the cab heating elements greatly over the wattage originally provided and as the low tension capacity of the motor generators was insufficient, high tension heating has been installed, which can be on in both cabs simultaneously. On relatively short journeys this is necessary or else at the end of the outward journey when the driver must change cabs, he encounters bad conditions again.

On this railway the locomotive servicing depot is not at a terminus and no freight crews book on duty there. There is, therefore, a « ferry » set of men to take out a serviced locomotive to a traffic point to exchange it with one required for periodic servicing.

As mentioned, common user and continuous service is so universal that it is virtually impossible to make comparisons with any other system.

In general the drivers of the electric locomotives are recruited from the former steam engine drivers, as the change in traction progresses. At the same time men are recruited directly for the job. In both cases, the men undergo a period of technical and practical training, because it has been noted that men used to steam traction, either on account of their age, or because of the harder work involved on a steam locomotive, or through lack of technical knowledge, adapt themselves very poorly to the characteristics of electric traction.

It is desirable to give the drivers clear descriptions of the electrical machinery which they are to handle so that they may know what it is expected to do. It involves, for an elderly driver, a great change in his work, but in spite of this after he has got over his first apprehensions, he generally adapts himself to the new techniques.

In general the drivers make a superficial inspection of the locomotives at the beginning and end of the run. During the latter inspection, they note any anomalies or damage which may have occurred in order to get these repaired; but except in the U.S.S.R., or in very special cases, they do not carry out any maintenance work; and if they do, it is always very elementary.

On the U.S.S.R. Railways the following jobs are done by the engine crews :

- — regulating the brakes;
- — checking the armatures, bearings, axles, toothed wheels and transmission;
- — replacing screws, bolts, pins and cotters;
- — eliminating leaks in the air conduits;
- — lubricant conduits and cleaning the outlets;
- — examining, cleaning and greasing the pantographs;
- — tightening up pins and the fastening of the suspension;
- — cleaning the contacts and segments;
- — replacing the brushes, cleaning the brush-holder and auxiliary equipment;
- — regulating the accoustic signals and replacing the diaphragms;
- — repairing any damage to the light signals; replacing fuses.

It is of great importance in order to obviate failures, to encourage drivers who immobilise locomotives in sidings, etc., at the end of the duty to report any defects, use of fuses, etc., so that « trouble fitters » may be sent out to do any minor repair necessary before the locomotive starts its next turn. Electrification telephones may be provided to enable them to send this information to the depot.

VIII. COST OF MAINTENANCE OF ELECTRIC LOCOMOTIVES.

It is very difficult to make accurate quantitative statements of maintenance costs in different countries on account of differing currencies and labour rates. It was, therefore, felt that the only figure which could be quoted should be as a percentage of capital value of the vehicles although even this basis may be complicated by a variety of differing circumstances.

Heavy overhauls appear to cost up to 3.8 % of value for labour and materials (2 % labour, 1.8 % material), but figures down to about 2 % total are quoted. Long period inspections cost very much less and these are of the order of 0.05 %.

Japan quotes 2.32 % for labour and 2.01 % for material for general overhaul on class ED with figures of 1.25 % labour and 0.62 % material for intermediate repair. Swedish Government Railways have maximum figures of 2.24 % labour and 1.15 % material for general overhaul, 0.95 % labour and 0.31 % material for intermediate repair. British Railways give figures of 1.03 % labour with 0.27 % material for intermediate repair. Very few of the BR locomotives have yet reached the stage of requiring general repairs.

In Section VI the repair schedule for S.N.C.B. was given in some detail and the costs which this Administration quotes are as follows :

	Labour %	Material %
Small maintenance	0.02	0.003 — 0.006
Big maintenance	0.03 — 0.05	0.003 — 0.006
Intermediate overhaul	0.21 — 0.50	0.16 – 0.30
General overhaul	2.45 — 2.70	0.70 — 0.75

There is also a considerable variation in man hours found to be necessary for carrying out repairs and some of these are shown in the table on next page.

In general it is not established that there is a definite relationship between maintenance costs and age of locomotives. Some of them state that these costs increase with the number of driving axles and when these are connected by rods, they are 25 % higher.

In U.S.A., however, where perhaps there is greater length of experience, they are able to quote an expression by which annual repair costs of two classes (GG-1 and P-5*a*) equated to year 1955 as base, increased in accordance with the equation :

$$y = 1\,000\ (a + 0.0893x + 0.11621x^2)$$

where x = age in years;

a = repair cost in dollars per unit per annum at age of one year;

y = repair cost in dollars per unit per annum at age x years.

From age 13 onwards to present age of 21 years costs followed the equation :

$$y = 1\,000\ (1.14a + 1.321x - 0.01319x^2).$$

Administration		*Man Hours per -*	
		General repair	*Intermediate repair*
Japanese Govt.	EH Type	5 390	2 970
	ED Type	3 260	1 770
U.S.A.	GG1 Type	5 955	
	P.5 Type	4 807	
	Other Types	4 025	
Swedish Govt.	BK Type	4 320	1 595
	Da Type	2 035	1 385
British Rlys.	EM1 Type		1 185
	EM2 Type		1 649

The man hour figures for SNCB are : —

Small maintenance	14 to 21
Large maintenance	32 to 40
Intermediate overhauls	450 to 850
General overhaul	4 000 to 5 000

Swedish Government Railways do not consider that costs vary much according to age of the locomotives but rather according to the age of the designs.

The final criterion is cost per mile or km which has two components — cost of maintenance and mileage run for that cost. The total cost must include both depot short period maintenance and workshop overhauls. Counteraction of any tendency towards rising costs is being sought in improvement in design, manufacturing and repairing methods, reduction of wear and by critical examination of costs. Standardisation of the best combinations is important in order that the benefit of good quantity production may be obtained in first costs.

SUMMARIES.

On the basis of the replies received, the following summaries may be formulated :

CHAPTER II.

Wear of rails and tyres.

The useful life of rails under electric traction is less than with steam traction, the reduction reported ranging from 8 to 50 %. This is not only due to electrification itself, but is also due to the more intensive services which normally accompany electrification.

Flange wear on tyres has been greatly reduced by the provision of track oilers placed at suitable positions at curves or on the locomotives. The reduction of flange wear is of great economic importance as approximately three times the flange wear has to be removed from the tread of the tyre to reform the flange.

Permitted limits of wear of tyres vary considerably and there does not appear to have been any scientific or mathematical approach to establish the safe limits of the tyre profiles.

It has not been possible to establish any relationship between the type of suspen-

sion of the motors and tyre or rail wear. Although at first sight it would seem logical to suppose that completely suspended motors should have a beneficial effect, nearly all Administrations have used only axle hung or nose suspended motors. Much attention is however now being devoted to the application of fully suspended motors and it is anticipated that appreciable reduction of track wear will follow.

Practically all new electric locomotives are being constructed in the double bogie designs which limit wheel diameter to a maximum of about 4 feet (1.250 m). This does no doubt increase tyre wear and rail end hammering, although there are no quantitative effects to report and it is considered that the obtaining of 100 % of locomotive weight for adhesion justifies this.

Tyre wear does not vary in any relationship to its machined diameter within the overall variation permitted between maximum and minimum thickness.

No general agreement is indicated to limitations of axle-loading to wheel diameter. There are indications that thought is being given to this and some Administrations have in mind a figure of 4.5 to 5 tons (axle load) per foot of diameter (14.5 to 16.5 t per metre). Such figures may however place onerous restrictions on locomotive design.

There is no direct evidence that speed of electric traction, by itself, contributes to rail or tyre wear.

A divergence of practice on the use of articulated or non-articulated bogies exists but up to the year of review articulated bogies appear to be more favoured and some Administrations report reduced flange wear with them, provided that there is a centralising force provided at the bogie ends.

Severe rail corrugation is only reported by one Administration.

CHAPTER III.

Maintenance of traction motors.

Design of traction motors should enable long life to be obtained before commutators need to be dismantled for returning. Mileages of 500 000 (800 000 km) should be obtained so that returning may not be necessary before the general repair stage of the locomotive is reached. There is a constant aim to make this mileage rise.

Attention is being given to the use of improved forms of insulation so that this will not cause a shortfall in life of traction motors.

There is division of opinion as to whether it is necessary to fit keys in armature shafts and pinions; the fitting of keys predominates.

It is universal practice to fit pinion on to shaft by shrinking on a taper.

Opinion is also divided concerning the desirability of keeping pinions and spur wheels mated.

Flashovers on electric locomotives appear to be rare and when they do occur, are generally caused by frost and snow, contamination by smoke, dust and exhaust from steam locomotives or by lightning.

There are, however, varying devices to assist in current collection :

— use of two pantographs or one pantograph with two shoes to reduce current collection per pan or pantograph;

— provision of two or more collecting strips on each shoe;

— improvement of the general design of the pantograph including provision of auxiliary springs to help shoe to follow the wire and of air vanes on high speed locomotives to keep shoe level;

— fitting of arrestors on locomotives to limit surges caused by lightning;

— instructions to train crews to limit current and fine division of resistances to assist in this;

— in a few cases, fitting of separate wheel slip indicators, but crews are also taught to deduce this from armature field meters;

— provision of arcing horns to prevent burning of commutator bars when flashover does occur;

— provision of high speed breakers with lower overload in place of fuses so that the current can be quickly restored after the flashover has occurred.

No reports have been received of the use of roller bearings for axle suspension of nose suspended motors.

CHAPTER IV.

Lubricants.

Grease lubrication is used generally in traction motor armature bearings.

Both grease and oil are used in axle or hollow shaft bearings.

Different characteristics are specified in lubricants to meet seasonal changes of temperature but generally this becomes a gradual change towards the desired properties by addition rather than complete changes.

Heavy grease or gear compound is used universally in traction motor gears.

No reports of the use of new lubricants (bisulphide of molybdenum or lithium) have been received.

CHAPTER V.

Wear on the pantograph strips.

Pantograph strips most generally used are flat strips of copper, aluminium copper, cadmium copper or copper bearing steel but there is a tendency to a more general use of carbon.

Graphite grease is the most usual lubricant. It can be applied quickly and easily and is effective.

When pantograph strips are worn, it is usual to change pans.

For a given material, strip life varies considerably, being influenced by climatic and atmospheric conditions and by speed and type of service.

Upward pressure of pantograph is generally specified to be between 16 and 20 lbs. (7 and 9 kg).

CHAPTER VI.

Organisation of maintenance and periodicity.

Electric locomotives are expected to run large mileages of the order of 500 000 miles (805 000 km) over a period of 4 to 5 years before requiring complete overhaul.

Daily inspections are of a very minor nature when they are carried out and it is normal to carry out depot inspections at intervals of 7 to 21 days.

Three principal components which may govern periods between depot inspections are pantographs, brake blocks and tyres.

Change of bogie at Works forms the quickest method of releasing locomotive for further service when tyres are worn to the limit.

Some Administrations replace heavy flange wear of tyres by deposition of weld metal without any subsequent machining.

CHAPTER VII.

Organisation of the service.

Common user of electric locomotives, without segregation to individual drivers or small groups of drivers, is practically universal, particularly on the longest services.

Unless there are particular local reasons, there is no need for locomotives to return to depot until required for periodic maintenance. They can be immobilised in sidings and stations or actually on stabled trains ready to start work.

Electric locomotives are capable of practically continuous working and all Administrations aim at keeping them on continuous duty, changing crews whenever necessary. No adverse effect of this system can be detected.

Adequate cab heating is necessary when locomotives work or are temporarily stabled in low atmospheric temperatures.

CHAPTER VIII.

Cost of maintenance.

The ultimate basis upon which maintenance costs can be judged is cost per mile or kilometre.

The general aim is to obtain a very high mileage before workshop heavy repairs with extensive dismantling are necessary and at the same time to keep day to day maintenance costs low. The items which may contribute to this aim are :

— critical examination of costs of repairing components;

— critical examination of frequency of repairs to components;

— improvement of design to reduce wear and frequency of repairs;

— improvement of workshop methods to reduce cost of repairs;

— specialisation of the manufacture of spare parts and components;

— training of staff for specific maintenance operations.

Although the cost of each short or long period inspection is low, the sum total per annum of depot maintenance is high — generally greater than Main Works maintenance and this gives considerable scope for scrutiny with a view to effecting reduced costs.

The overall requirement, for which the electric locomotive has the possibility with suitable design and manufacture, is extensive user with minimum of idle periods, together with long periods between withdrawals for maintenance purposes.

Only one Administration quotes a relation between maintenance costs and age of the locomotives. Another point of view is that it is more closely related to the age of design.

SECTION III. — Working.

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QUESTION 5.

a) Handling facilities in the goods depots for consignments in less than carloads, containers. General arrangement of the depots. Liaisons between the staff of the depot and the delivery services.

b) Railway problems regarding the introduction of general palletisation of packages,

by M. MARCHAND,

Ingénieur en Chef à la Direction du Mouvement à la Société Nationale des Chemins de fer français.

Special Reporter.

Question 5 concerning the parcels traffic and its palletization was the subject of the following two reports :

Report by M. J. DORJEE, General Manager of the General Transport and Forwarding Company Van Gend & Loos Ltd (Holland). (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, Netherlands, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories). (See « Bulletin » for March 1958, p. 231.)

Report by M. MARCHAND, Ingénieur en Chef à la Division du Mouvement à la Société Nationale des Chemins de fer français. (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, West Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia). (See « Bulletin » for April 1958, p. 447.)

As the problems arising in connection with the handling of parcels in the goods depots are extremely complex and differ very considerably according to the country on account of the great differences in the importance and nature of this traffic, the reporters tried to draw up a very detailed questionnaire with the object of avoiding any gaps and of collecting together numerous data which might give a precise idea of the most interesting solutions introduced by the different Administrations. However, as questions of the organisation of the transport, the installations in the depots, the means of handling and methods of operating the depots are interdependent, it was difficult to draw up a detailed questionnaire which would not involve repetitions. The reports which went into the replies to the questions asked point by point may perhaps have left a certain impression of heaviness due to these repetitions. The reporters ask to be forgiven for not being able to help this: they think that their aim, which was to collect as much interesting information as possible before sorting out the general ideas and formulating the summaries, has been achieved. They wish to thank the various Administrations who have helped them in this way.

Moreover, they made it clear that the proposed questionnaire was not limitative

TABLE 1.

Country or Administration	Annual tonnage (in tons)	Percentage of total freight tonnage	Traffic evolution	
			Increase	Reduction
United States, Class 1 Railways	7 000 000	0.5		X
England	5 000 000	1.8		X
Soviet Union	4 970 000	0.3	X	
Federal Germany	4 940 000	1.93	X	
India	4 840 000	4.2	X	
Spain	4 650 000	13	X	
France	3 700 000	1.8	=	
Poland	2 280 000	1	X	
Switzerland (Federal Rys., Bernese Alps and Rhaetian Rys.)	2 225 000	8.4	X	
Italy	1 735 000	3.2		X
Holland	1 400 000	5.3	X	
Sweden (State Rys. and Private Rys.)	1 345 000	2.7		X
Norway	not indicated	12		X
Finland	1 070 000	5.5	X	
Jugoslavia	1 060 000	2.3	X	
Portugal	800 000	20	X	
Denmark	755 000	12.3		X
Belgium	660 000	0.92	=	
East African Railways	650 000	16.6	X	
Austria	535 000	1.15	=	
New Zealand	495 000	4.6	X	
Ireland	450 000	20	=	
Hungary	425 000	3	X	
Lower Congo-Katanga	335 000	18	X	
Colonial Transport Office	not indicated	5 to 10	X	
Greece	140 000	10		X
Algerian Railways	135 000 (1)	2.2	=	
Malaysia	100 000	5	X	
Luxemburg	35 000	0.19	=	
Ethiopia	25 000	10		
Viet-Nam (South)	7 000	2		X
Cambodia	900	0.0035		
South African Railways	particulars not given		X	

Excluding express (G.V.) parcels.

but that they would welcome any additional information and all the other general or particular facts which could be supplied. In actual fact, none of the Administrations which replied offered any further details of this kind, which has led the reporters to conclude that the questionnaire drawn up covered the field satisfactorily in spite of the diversity of circumstances found, as regards the essentials of the solutions adopted in each country.

In addition, we would point out that the reports did not deal with parcels traffic carried in small containers, as this equipment was the subject of a detailed study in 1952 (1) by the International Railway Congress Association.

Nor was any allusion made to « grouping » organisations which work in collaboration with the railway by assuring the collection and distribution of parcels, letting the railway deal with the actual transport; such traffic, carried in full grouped wagon loads, lies outside the scope of the present study; but although not included in the parcels traffic statistics, it certainly contributes to retaining some of the traffic in the railway sphere, whilst freeing the Administrations from the trouble of handling and sorting the parcels.

GENERAL.

The appended Table I showing the importance of the parcels traffic carried on each Railway, as well as the percentage of the total freight traffic this represents, brings out the very great differences in this respect in the various countries which replied to the questionnaire.

In absolute value, the parcels traffic carried varies between a few hundred thousand tons to several million (some dozen countries are in this latter case), and in relative value, the parcels traffic represents from 0.3 % or 0.5 % to 18 and 20 % of all the freight traffic.

Even within the group of ten countries which annually transport from 2 to 7 million tons of parcels, the percentage represented thereby varies from 0.3 % to 13 %.

Obviously, the geographical and economic structure of each country, the more or less industrial character and more or less planned nature of its economic activity, the level of development and organisation of the whole of the various existing methods of transport influence the nature and amount of the tonnage of goods to be carried as well as the method of transport (in full loads or by parcels traffic, by rail, road, sea or river traffic).

As M. DORJEE says in this connection : « Every Administration will want to remain constantly aware of this coherence for the evolution of these structures is decisive for the evolution of their parcels traffic and for the measures to develop, adapt and — if necessary — to defend same. »

However, if it sets each country its own particular problems, the parcels traffic always presents the same essential difficulty.

« One of the general characteristics of « parcels traffic » — to quote M. DORJEE again — is that it always concerns « broken transport », either already within the railway itself (transhipment) or at the door to door transport... and it is this characteristic in particular which defines the whole contents of Question 5 and demands all care and attention for what it embodies (handling facilities, arrangement of the goods depots, delivery services, palletization...) ».

This phenomenon of the breaking up of the journey which also exists in the case of transport by full wagon loads which are not run as complete trains is the weak link of the railway, as it increases both the costs and the total transport time, and it is felt particularly in the case of the parcels traffic.

Moreover, the parcels traffic is particularly susceptible to competition from road transport.

The road hauliers are free in most countries to select the routes over which they run and the kind of traffic they carry (heavy and « profitable » parcels); in this way, in many countries where no healthy coordination of the freight traffic was drawn

(1) Special report by M. F. SAUVAJEAT. See « Bulletin » for June 1952, p. 507.

up in good time, they skim the parcels traffic twice over — the kind of freight and the routes — leaving the railway to carry a mass of heterogeneous parcels, often light weight bulky parcels, of very varying dimensions to diverse destinations. Certain Administrations have stressed this state of affairs which tends to restrict the possibility of making up through wagons and makes the handling and stowing of the parcels more difficult and also increases the risk of damage.

As a public service, the Railway Administrations have to accept all this freight: it is very general for there to be no strict regulations limiting the size of consignments which can be handed in as parcels: the only factor is the choice of the client which may be guided by tariffs encouraging transport in full wagon loads. As for any limitations which may exist on the parcels themselves taken individually, these are aimed above all at removing from the circuit through the goods depots those parcels which it would be too inconvenient to handle. Such limitations are moreover not very restrictive [1].

* * *

Such are the difficult and costly conditions under which the railway has to work when dealing with the parcels traffic.

This explains the high cost of such transport, and consequently the high rates and the need to make use of organisations which whilst improving the quality of the service from the angle of retaining the traffic, the rapidity and regularity of its transport and the additional facilities offered to clients (door to door services) are at the same time the most economical thanks to :

— the reduction in the number of transhipments the goods undergo;

— the better user of the wagons obtained;

— the reduced handling costs owing to the modernisation of the installations and the mechanisation of such operations.

The first two requirements are linked together to some extent, and this interdependence may, as the two reports showed, have a variable character according to the Administration concerned; in reality a sort of compromise has to be made between the average number of transhipments during transport and the average wagon load, taking into account in particular the cost of handling in conjunction with the level of wages and the desire or the actual need to a greater or lesser extent to realise rapid transport.

In the case of small countries, the average load of the parcels wagons is relatively of secondary importance, and it is natural that running such wagons should be subject to less restrictive requirements as regards the load, the major concern being rapid transport.

On the contrary, in large countries, with a drawn out railway system and long distances between the large towns, poor user of the wagons over long runs has bad results. In this case, the need to make up a good load for the wagons may predominate even at the expense of delays in transport.

These considerations explain the great differences of opinion revealed in the replies from the point of view of the organisation of handling operations, the need for stacking the pallets in the wagons, etc.

* * *

Having made these essential distinctions, it goes without saying that within their basic framework, all the Administrations endeavour to reduce the number of transhipment operations undergone by parcels.

[1] One interesting point concerning the acceptance of small parcels is reported by the Norwegian Railways which are able, when such consignments would very likely cause delays in the handling and transport, to require such parcels to be sent in cases, baskets or sacks, or grouped together into larger parcels. This measure, which is aimed at avoiding upsetting the railway services for client's requirements deserves particular mention, although it is not currently applied.

This is the best way of reducing unproductive costs of handling and the risk of damage which increase the costs and appreciably worsens the commercial position of the railway.

With this object in view, the now classic organisation will be adopted with only slight variations, whereby the railway system is divided up into zones in which the traffic on arrival and departure is concentrated into a centre station sited in a town with important local traffic from which the whole zone can be served conveniently either by rail or by road.

Each of these centres, with its own traffic and that of its zone, then has to deal with a sufficiently large volume of traffic to justify linking it up with all the other zonal centres by through wagons, or at least with a great many of them.

The following considerations generally dictate the size of these zones :

— on the one hand, the transport times within the zone itself must not exceed a few hours so that parcels coming in to the centre during the night arrive at their destination stations during the morning and those handed in at the end of the afternoon in the consigning stations reach the centre station during the night;

— on the other hand, it is of the greatest interest to make the zones as extensive as possible in order to avoid having to tranship parcels. For a given railway, the probability of forming through wagons between zone centres varies in fact in the opposite sense to the square of the number of zone centres adopted. Extensive countries, which cannot allow lightly loaded wagons to be run, are obliged by this fact to have rather extensive zones.

The basic organisation of the zone centres can be amended in order to limit transhipments in such centres, for example when it is possible to make up through wagons at one station of the zone or again by a group of stations by using pick-up wagons for a given destination; but in any case the classic organisation with zone centres results by its very principle in :

1) a considerable increase in the number of parcels carried directly from the consigning station to the destination station when the zone centres coincide with localities having a large amount of traffic of their own;

2) to limit the number of stages to which the other parcels are subjected.

Only small countries with a very dense population can run through wagons between all their zone centres; in other countries intermediate calls for transhipment are inevitable for a proportion, often a considerable proportion, of the long distance consignments; it is then generally advantageous to concentrate such calls in the zone centre stations which already have to deal with transhipment operations and are suitably placed geographically, i. e. in principle at important railway centres of the network.

In his report Mr. DORJEE has reported the reservations made by several countries which consider that they do not follow the classic organisation because most of the parcels trains, if not all, have an optional character in their case, as they are only run when certain conditions as to tonnage are fulfilled. Mr. DORJEE remarks that the classic organisation of the zone centres does not necessarily imply the use of « regular » services, since all the Administrations in practice make use to a varying extent of « optional » services.

In this connection, it should be noted that if connections by means of through wagons have the advantage of making it possible to load the parcels directly into the wagons at departure, connections by means of optional wagons presuppose a preliminary knowledge of the traffic.

The organisation of transport in countries with a planned economy favours this operation. In the U.S.S.R., the railway is informed of the traffic it will have to carry (24 hours in advance), but the « authorisation » which they appear free to give or refuse leads us to suppose that at times it

is the traffic which is regulated by the transport available.

Administrations in countries having a liberal economy naturally experience greater difficulties and must so organise themselves as to be able to recognise in advance the traffic that can be dealt with by optional wagons; for this purpose the methods used by certain Administrations consulted consist :

— either in holding the goods in the departure or transhipment stations, which involves having bigger platforms and means additional handling;

— or planning the work in the transhipment depots by means of the transport documents when these accompany or are sent on in advance of the wagons.

In the case of extensive Railways with sufficiently large goods depots, holding the parcels at the departure station for one or two days may be an effective means of multiplying the number of direct regular or optional wagons; the loss of time resulting from holding the parcels in this way is often made up by the faster because more direct transport. This solution has been introduced on certain Railways like those of the U.S.A., U.S.S.R. and India.

We think it is necessary to remove any risk of misunderstanding before the Madrid discussions begin, and we agree with Mr. DORJEE that the more or less extensive development of « optional » parcels services is only one particular aspect of the organisation of transport and in general does not appear likely to destroy the principle of the classic organisation by zone centres.

GOODS DEPOTS.

The goods depots have been dealt with in the past in a relatively summary fashion with the essential object of getting the depot and handling of parcels under cover from the weather; but an examination of the reports shows that all the Administrations are now endeavouring when modernising, or even when rebuilding to meet other needs, of a commercial or technical order, to offer their clients greater convenience and adapt the buildings more closely to the handling operations that have to be carried out in them.

Whether it is question of small or large depots, in this order of ideas mention must be made of :

— including commercial offices within the depots suitably arranged and sited for client's requirements;

— suitable lighting by day and night and ventilation of the buildings in order to improve working conditions and output;

— making the floors perfectly level, very strong, smooth, and if possible antislip even in wet weather;

— making the platforms at exactly the same level as the wagon floors in order to avoid differences in level prejudicial to handling when loading or unloading the wagons;

— setting up the service and maintenance posts required for the new handling machinery (including battery charging equipment and fuel pumps, etc.).

But quite apart from these general tendencies a particular evolution of importance is noticeable in the case of the depots at large stations characterised by the grouping of the different operations within these vast units designed with the concentration of the traffic in mind. This evolution is a natural consequence of mechanised handling and is also the result of the idea of concentration of the routing in order to reduce the number of transhipments for the transport as a whole.

In many large stations in fact, the Railways have often merely built a series of buildings of standard rectangular form, whose modest dimensions were in fact adequate for the handling distances of that period, assured almost entirely by two-wheeled barrows.

The number of buildings were then determined and if necessary subsequently added to according to the amount of traffic, which was relatively easy in the case of the

services for which they were designed; but the dispersal of the traffic in these numerous scattered buildings not only makes it necessary to divide it up according to its various basic functions : arrivals, consignments, and if necessary transhipments, but even to set aside buildings for given geographical relations, or for certain kinds of goods. Such an arrangement, which is often inconvenient for clients, can only give rise to difficulties and additional operating costs from the point of view of handling and making up well loaded long distance services.

The principles of concentration which are essential for the general organisation of the parcels traffic must necessarily be extended to the interior of the depots, and it is desirable, to facilitate the transport, to group all the arrival, consigning and transhipment areas in order to obtain a single goods depot; for example it is easy to understand that the wagons leaving a single goods depot can carry more traffic since they collect both the parcels consigned from the town and those which arrived by wagon for transhipment.

It is also easy to understand that the staff and handling equipment can be suitably distributed during working periods over the different areas, much better than in the scattered depots.

This had led many Administrations during recent decades to set up single goods depots, though there is considerable variation from the point of view of their realisation.

It is not in fact a question of making a single building, but of juxtaposing the various areas into a whole with good railway services, practical road connections and, to assure convenient direct connections between the different areas, with trucking circuits for the parcels over floors adapted for the rapid circulation of mechanised handling equipment.

Naturally, such rational arrangements need to be the subject of thorough organisation studies, taking into account the operating and handling methods proposed, the expected traffic, and the possible future evolution of this traffic.

In particular, it is prudent to allow generous parking space for lorries in order to allow for the growth of the towns and their suburbs or even the development of lorry traffic due to the replacement of the railway services by road services in the zone served by the centre station; at the same time it is indicated to provide suitable parking space for the parking or garaging of the road vehicles used for the collection and distribution services.

It goes without saying that, if only on account of the volume of traffic that can be dealt with, these single goods depots are the most suitable for the high output mechanised handling equipment, and in the opposite sense, their working can only be considered when such equipment is available.

However, everything is done to make them as compact as possible, in order to reduce the length of the transhipment runs.

Amongst the arrangements of up to date single goods depots, two types, examples of which were mentioned in each of the two reports, deserve special mention :

— single goods depots with « U shaped platforms »;

— goods depots « without platforms ».

In the former, all the service sidings, loading and unloading sidings, are dead end sidings and the trucking platforms parallel to the sidings are connected by a platform at right angles to them — known as the « front platform » — which links up all the platforms; therefore all the platforms together form a U with several branches. The consigning area is generally on the front platform so that there is a very short distance from it to the loading platforms. As for the arrivals area, this is necessarily at one side on a big platform served by a courtyard.

The great value of single goods depots, of this short, dead end type, is to do away with all interference between the shunting of the wagons and the trucking of the parcels; this avoids the movable bridges

used in depots served from both ends or in unduly long depots, the use of which hinders the running.

The goods depots « without platforms » designed in Great Britain and afterwards adopted by some Commonwealth countries and in France are particularly well adapted to very large depots having to deal with a great volume of traffic.

The basic idea behind this organisation consists in dividing up into two phases the handling and sorting of the parcels.

A first sorting takes place when the wagons are unloaded, separating them into a few preliminary lots, about ten in all. Unloading is done by means of an unloading machine or conveyor belt at the ends of which are the distribution trollies, each of which receives its preliminary lot.

The floor of the trollies is at the same level as those of the wagons or platforms, which makes these trollies into mobile platform units.

The loading site consists of yards surrounded by loading sidings without platforms (hence the name goods depot « without platforms »).

Each preliminary lot, conveyed on its trolley to which a tractor is coupled up, is then taken into a yard or alongside part of the arrivals platform according to its allocation when the wagons were unloaded. This is the second stage in sorting operations.

The trollies are also used to sort the parcels sent to the consignment platform and transfer them to the wagons.

It is easy to see that carrying out sorting operations in two stages simplifies this very considerably when large masses of individual parcels have to be sorted out for a very great number of different destinations.

This organisation has however lost some of its interest since the appearance of palletization, which has as its object precisely the simplification of sorting operations, especially in the case of transhipments.

Moreover, in goods depots without platforms, the putting into position of the elevator trucks to stack the pallets in the wagons presents difficulties and the solutions adopted to date are as far as we know merely palliatives of doubtful merit.

Methods of handling and working in the goods depots.

Those chapters of the Reports dealing with the methods of running the goods depots show that there are a great many different ways of doing this, which often differ from one Administration to another, both in the case of consignments and arrivals and for the transhipment of goods.

This is doubtless due to the fact that the consigning or delivering of a parcel is not a simple operation but on the contrary they are both the complex result of numerous elementary operations, each of which can be done in various different ways; thus, for example, when a parcel is consigned by rail, it has to be taken into the depot, booked, weighed, labelled, transferred to a wagon, stowed in the wagon, and at the same time the necessary corresponding transport documents have to be prepared.

It is also due to the fact that the method of running the goods depot is linked up with the basic ideas held regarding the general organisation of transport, the installations in the depots, and the available methods of handling.

For example, if the parcels are sent on by wagons which are mainly regular or mainly optional, this will profoundly modify the method of working to be adopted in the consigning area or transhipment depot, as will the fact of having a single goods depot or specialist depots, palletization or not, etc.

The detailed description of the various methods used by the Administrations was given in the reports which recapitulated the information received. We will merely state the most general considerations and tendencies or stress any interesting innovations.

As far as the actual handling is concerned, certain Administrations, though not very many, seem to practice the systematic

arranging of the parcels on the platforms before loading then up in order to:

— favour stowing operations by arranging the parcels according to their weight, shape and nature;
— and on the other hand, to facilitate the running of optional wagons.

However, the majority of Administrations have for a long time preferred « direct loading » in particular because this has the advantage of reducing handling operations by speeding them up and because in addition it makes it possible to limit the size of the platforms to that strictly needed for trucking the parcels.

In this case, however, it is necessary for the loading trollies to be of sufficient capacity to allow of all the consignments being forwarded from the depot to be put on them at one and the same time; special steps must also be taken for loading the distributing wagons taking multiple lots of parcels, but these difficulties are considered of little importance compared with the great simplification of handling operations thereby achieved.

We will see however that palletization can to a certain extent modify this tendency, either because of the fact that the facility with which the pallets can be handled makes it possible to put the loaded pallets on to the platform without inconvenience before they are loaded into the wagons, or because in certain cases it is desired to make up palletized loads with parcels placed temporarily on empty pallets left ready by the wagon doors.

As far as the other operations involved in handling and transport are concerned: checking, weighing and labelling, the two reports state that there is a fairly general tendency to simplify methods.

On consigning, for example, it is the current practice on a certain number of Railways to be satisfied with a simplified check of parcels handed in by regular clients, in practice merely a count of the numbers consigned.

In the same way, parcels with a standard known weight are no longer weighed.

In Sweden, such practices have been made official and the railway makes agreements with certain consignors by which such formalities as checking and weighing are no longer necessary; such agreements moreover free the railway from responsibility in case of error.

The labelling itself which certain Administrations use so that the staff handling the parcels know what routes they are to go by (other Administrations give such information on the transport documents and compare the two before the parcels are loaded into the wagon) is sometimes also entrusted to regular clients, the railway merely making occasional checks on their accuracy.

Such practices have three advantages:

— they develop the habit of invaluable collaboration between the railway and its clients;
— they reduce the time between the acceptance of a parcel and its departure, which speeds up the transport;
— they make it easier to meet peak periods of work, which occur in most cases in the large consigning depots about 6 p.m.

In connection with this latter, it is often advantageous to have « town's offices » in the large cities or « client's offices » in the case of very important clients where all the preliminaries in connection with the transport can be decentralised and brought closer to the consignors;

In the same order of ideas as regards simplification of the operations in connection with transport, the example of those Administrations should be stressed who will only accept small or light parcels (up to 50 kg = 110 lbs. for example) carriage paid.

Without being any serious hindrance to business, this measure allows of simplifications in the operations of taxation, checking on departure and above all on arrival, since there is no longer any need to check the parcels against the transport papers.

As we will deal with the question of unloading and checking on arrival together with collection and delivery, we will merely mention that when transhipping, certain Administrations carry out a more or less extensive check of the goods and may even

make certain records, either by making complete or summary lists of the parcels that are being reconsigned, or by listing the consignment notes... with the object, so they state, of being able to determine responsibility in the case of loss or damage, check that the goods are going by the proper route, and if necessary make studies of traffic currents.

However, many Administrations have given up such formalities in view of the complications they involve.

HANDLING EQUIPMENT.

In the small goods depots, the two wheeled barrow, a practical and cheap method of handling as long as the distances remain small, is still the basic handling equipment.

In large goods depots, where long distances have to be covered, it is not rational to carry the parcels practically one by one, especially the small parcels; on the contrary, they have to be grouped together for similar destinations (wagon being loaded, delivery bay) into larger « handling units » before being moved.

For this purpose, most Administrations have used essentially up to recent years either hand trucks (average sized depots) or motor trucks and trailer or semi-trailer trucks (large depots). The latter can be coupled up together into trains of trucks hauled by a tractor.

Certain Administrations also use overhead driving chains to move the trucks, or driving chains fitted in the floor. Some of them state that they are satisfied with this arrangement; others report that to free the trucks from the driving chains involves a large amount of labour which is badly used. There are in fact many points at which the trucks have to be freed and each has to be staffed by men responsible for noting the numerous destination indications before finding one which concerns them.

The use of long conveyor belts (moving floors) carrying the parcels through the depots to bring them in line with the wagons or bays, or delivery lorries, has the same drawback; though used at one time by some Administrations, this method of organisation is hardly ever used at the present time. Designed for individual handling of the parcels, it is moreover very inconvenient for transferring large units (containers or pallets for example).

The « handling units » normally are made up in the consignment areas or near the doors of the wagons being unloaded; however the grouping of small parcels for similar destinations (wagons being loaded, delivery bays) is often done more conveniently by sending them through special sorting areas. In the large depots, where the parcels have to be sorted for a great many destinations, it is more or less essential to pass the parcels through one or even several sorting areas.

Some Administrations have introduced semi-mechanisation of these sorting operations; for this purpose they use :

— in the area where the wagons are unloaded, unloading machines or short conveyor belts, which can be used for sorting, are of value for the preliminary sorting provided there are not too many destinations involved (goods depots without platforms in particular);

— in the areas where small parcels are sorted, sorting tables (turning or not) connected up with conveyor belts.

However, the importance of sorting problems has been limited within the last twenty years by the extended use by clients of small containers of 1 to 3 m^3 capacity, to forward in particular small parcels; this development is likely to be largely superseded by palletization : when clients hand over handling units that are already made up it saves the railway having to do any sorting to make them up.

* * *

The pallet is an excellent medium for constituting handling units and certain Railway Administrations have already adopted it for some years in order to assure the movement of parcels within the depots.

In general, the pallet of the dimensions currently used makes it possible to form handling units weighing some 200 to 1 000 kg according to the kind and shape of the parcels. It also makes it easy to handle heavy parcels which it is always very difficult to put onto the trucks owing to their height.

Owing to its shape and the ease with which it can be picked up, especially when it has four openings, the pallet is a particularly practical handling and stowing apparatus, with a very universal character. Its appearance has therefore to a certain extent caused research and trials into the mechanisation of the individual handling of parcels to be given up and consequently also the sorting of parcels.

The types of machines for handling pallets now in service are numerous [1], and can be classified into three large categories :

- hand pallet carriers, used to move pallets over short distances (generally less than 50 m);
- mechanical pallet carriers, used to move them over longer distances (about 50 to 150 m);
- fork lift trucks, mechanical, either with a driver or driven from alongside, which are used not only to move the pallets over distances of the same order as above, but in every case where it is necessary to stack pallets.

It should be noted, however, that owing to the fact that they cost almost as much as fork lift trucks with drivers, trucks driven from alongside are not generally selected by the Administrations.

When pallets have to be moved for more than 150 m, many Administrations use trailer trucks which can take two pallets (sometimes three) and make these up into trains which are hauled either by a tractor, or even by the fork lift truck used to put the pallets on the trucks when this is sufficiently powerful and fast.

[1] We have included in the summaries the considerations covering these machines for handling pallets and the wishes expressed in this connection by the Administrations.

ROLLING STOCK USED FOR TRANSPORT.

With very few exceptions, all the Administrations use for the parcels traffic their current types of wagon and did not express any desire to build specialised stock. The ordinary characteristics of these wagons enable the parcels to be loaded without difficulty.

The Netherlands Railways which are the only railway in Europe to use special wagons having strictly identical dimensions for the transport of parcels, report the advantages of having homogeneous stock, especially in the depots where the wagons being loaded have to be divided up into several parallel rakes only one of which can be reached from the platform. As it is necessary to pass through the wagons of one or more rakes, this can be done without difficulty. This operating facility undoubtedly makes it possible to avoid having to make costly extensions to the depots at certain stations, but having specialised stock also involves additional immobilisation of the rolling stock as well as increased empty mileage. This is the reason why Administrations with a more extensive system are not considering using it.

However, with the development of palletization the need to be able to work the fork lift trucks in the wagons and carry out the stacking operations makes stronger floors and sufficiently wide and high doors desirable.

For some years the I.R.U. (U.I.C.) studies for new designs of rolling stock have been orientated in this direction.

Some Administrations carry out certain sorting operations during the run in the trains used for collecting and delivery purposes. The use of this method has led some of them to provide special equipment inside the wagons to facilitate the work of the staff travelling on the trains. It would appear that this also leads to having a certain special stock of wagons for collecting and distributing parcels.

The Railways of the Soviet Union have considerably developed the use of large

containers to carry the parcels traffic since nearly half their traffic is carried in this way. These containers are loaded on the usual type of flat wagons and are handled in depots specially arranged for this container traffic. The method is of undoubted value within the framework of the « planned » organisation of the parcels traffic, enabling the Soviet Railways to form large load units though these do not always attain the full capacity of a wagon.

UNLOADING AND CHECKING ON ARRIVAL.

Collection and delivery services.

In general, the Railway Administrations consider that their part in the transport of parcels cannot be limited to the railway journey, and that they must also concern themselves with the door to door collection and delivery.

However, whilst certain Administrations only appear to consider that collecting parcels presents a certain commercial interest and take steps to do so or have it done by subsidiary organisations, the very great majority of Administrations take a great interest in delivery to domicile and organise this very carefully in order to satisfy their clients completely.

Certain Administrations even consider that making delivery to domicile as a standard practice improves the commercial position of the railway. The consignee no longer has to bother about the end part of the journey and the railway in this way assures door to door transport as far as he is concerned.

This is why several Administrations always deliver to domicile and even include the cost of so doing in the rates.

They carry this out either directly themselves, or through affiliated Companies, or private hauliers with whom they have a contract. In this case, the Administrations reserve the right to keep a check on how the service is carried out, so that irregular or unduly expensive deliveries do not compromise its commercial position.

If it involves the railway in new obligations, delivery to domicile in all cases also has certain definite advantages :

— it simplifies and considerably speeds up sorting when the wagons are unloaded, as the parcels only have to be divided up amongst a small number of bays corresponding to the different delivery areas, as well as into a few special bays (important clients, special kinds of goods, etc.);

— it makes it unnecessary to advise clients of the arrival of their parcels;

— it makes it possible to deliver the parcels much more quickly which improves the service given and also makes it possible to reduce very considerably the area set aside for arrivals, as the parcels remain in the depot for a much shorter time.

This latter advantage is of particular value at a time when inevitable accumulations of parcels become more and more numerous, especially at the end of the week, in countries in which many industries and businesses close down for two consecutive days (5 day working week).

On the technical plane, the types of delivery vehicles are somewhat varied; the Administrations are agreed in wishing for a certain degree of standardisation, especially in the case of the floor levels to make these approximate to that of the platforms in the depots. The vehicles used must also be suitably equipped for loading and unloading heavy parcels, small containers, box-pallets and pallets; on the other hand, it does not appear essential a priori for this equipment to make it possible to stack the pallets.

* * *

The two reports bring out the great diversity in the methods followed for handling and checking the parcels in the arrival areas.

First of all, it should be noted that amongst those Administrations which deliver to domicile as standard practice, some

load the parcels directly into the delivery vehicles; in this way, they avoid putting the parcels down on the arrival platforms so that these need not be so large, but this method presupposes a very broken up system of delivery : since the parcels cannot be grouped in the delivery vehicles as a function of the delivery circuits, the number per vehicle must be limited and care taken in particular to avoid putting parcels addressed to different destinations on top of one another. This means that the vehicles will only have a relatively small useful capacity, which increases the cost of the delivery services.

However, the way in which parcels are checked upon arrival depends to a very large extent upon the way in which the parcels are dealt with upon arrival : put into bays, loaded directly onto the delivery vehicles, etc.

The most widely used method of checking them is the following :

— when the wagons are unloaded, the parcels are sorted, then placed in different parts of the depot corresponding to their respective destinations, i. e. in bays allocated either to the different delivery areas, or to all the parcels to be collected at the station or handed over to agreed hauliers or important clients, or again to certain categories of parcels which are delivered separately (fish, perishable foodstuffs, empties, very heavy parcels, etc.) by the road services.

These operations of transferring the parcels to the bays are sometimes carried out in two stages : in the first stage, the parcels are put without having been checked into various temporary sites near the place where the wagons are unloaded. In the second stage, they are checked before being transferred to the delivery bays at the edge of the platforms.

To reduce the amount of handling certain Administrations prefer to carry out checking either when the wagons are unloaded, or after putting the parcels directly into the delivery bays. The transfer of the parcels from the wagons to the bays is generally done in one stage in such cases. However, the small parcels are usually sent to a special sorting area, and checking can best be done when they are being taken to this sorting area.

In large depots, the small parcels are sometimes delivered separately from the other parcels.

As for the methods used for unloading, these are also extremely diverse and linked up to a certain extent with the way in which checking takes place.

On certain Administrations, unloading is the subject of strict planning; the transport documents are examined first of all at the Goods Office and marked to show in what bay the parcels are to be put; they are then handed over the handling staff who merely have to obey these instructions.

On other Administrations, the handling staff on the contrary are responsible for deciding, either from the labels on the parcels, or from the transport documents if these are given them beforehand, into which bays the parcels are to be unloaded temporarily or finally.

This second method presupposes that the foreman in charge of unloading operations is sufficiently well versed concerning the way in which the parcels have to be delivered; it has the advantage, especially when it depends simply on the labels, of allowing the wagons to be unloaded as soon as they are brought up to the platform.

Likewise different methods are used in handing over the parcels to the delivery services.

In fact, the methods of unloading, checking, transfer to the delivery bays or handing over to the delivery services are closely connected with each other. They all have advantages and drawbacks, and we have not formulated any general recommendations on this subject.

PALLETIZATION IN TRANSPORT.

The reports which recapitulated the information supplied by the Administrations showed that many of them already make use more or less currently of pallets for handling operations within the depots;

only very few of them as yet use it during actual railway transport.

Palletization of the parcels traffic during transport is however becoming of increasing interest for all the Administrations as the use of pallets shows itself to be a technical improvement of general interest, an advantage for both client and the railway.

This may take two forms [1] :

— in the first, the railway, in order to avoid handling operations or to facilitate it, makes up the pallets itself at the time of consigning, carries out the transport on pallets and in principle depalletises in the arrival area of the destination station; this is internal palletization on the railway;

— in the second, the whole of the transport is palletized, from the premises of the consignor to that of the consignee; this is what is known as « general palletization ». This method is the current practice in only very few countries; others are beginning to make use of it.

Administrations with some experience of palletisation in railway transport have stressed that this technique reduces and simplifies handling operations and is a satisfactory solution to the problem of trucking heavy parcels (difficult to solve to date) or fragile parcels. In this way, the quality of the transport is improved both as regards the reduction in damage and the speeding up of the journey.

Palletization, however, makes it necessary for the staff, especially those employed in consigning duties, to take very great care in carrying out the tasks for which they are responsible.

On the one hand, as the parcels grouping unit (the pallet) is smaller than the wagon, the « pallet » transport plan is more detailed than the « wagon » transport plan and involves very careful sorting; on the other hand, the arranging and stacking of the pallets and parcels in the wagons must be done methodically in order to avoid loss of space and to obtain stable loads, capable of standing up to the normal vibrations and shocks which occur during the run.

Some Administrations have reported that the adoption of palletization was met with some reserve by the Staff at first owing to the above mentioned difficulties which are inherent in the method itself, as well as the usual difficulty in changing habits. But the same Administrations also said that the staff were becoming more and more interested in palletization, especially the staff responsible for making up the pallets who understand that the delicate job for which they are responsible saves the staff responsible for handling.

This method moreover definitely improves working conditions by reducing fatigue and reducing the risk of accidents during handling. In addition, like every method of a higher technical skill, it is the source of promotion in the working scale, especially owing to the use of mechanised equipment.

Experience proves that the percentage of parcels now palletized is high; it covers — state those Administrations who have the most developed palletization of their transport — 70 % of the traffic and sometimes more.

However, packing the parcels on the pallets give rise to a delicate problem : sticking the parcels together and bonding them are solutions which can only be used by consignors themselves, in the case of pallets loaded with homogeneous parcels. The staff must therefore be taught to make up palletised loads by packing the parcels carefully so that they hold each other in place.

The use of box-pallets reduces these difficulties; they are particularly valuable for the transport of small parcels. But box-pallets are expensive; in addition, they take up a lot of room, either in the wagons when

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[1] We might mention in addition a somewhat special use encountered in the United States and Soviet Union; in these countries, the pallet is sometimes used to carry parcels during their transport from the consignor's premises to the station, or from the station to the consignee's premises, though the transport in the wagon does not take place on a pallet.

being returned empty, or in the handling areas waiting to be used. Their use must therefore be restricted to a reasonable proportion, if the cost of palletization is not to be excessively increased.

Mention may by made in passing of the use of closed box-pallets which advantageously replace small containers because they are much less expensive and easier to handle. Apart from the special case of transit transport under customs seal, in which they can be used with advantage, they are intended above all to be loaded by clients themselves so that they come within the field of general palletization.

One controversial question is the effects of palletization upon the useful wagon load.

In his report Mr. DORJEE states that Holland and the Soviet Union estimate that palletization involves a reduction of 10 to 15 % in the wagon load and have concluded that it would be irrational to palletise long distance traffic, for example on runs of more than 300 or 400 km (186 to 248 miles). In our own report, we stressed that the Administrations concerned did not think there was any fear of any considerable reduction in the transport capacity of the wagons. The statements made in this connection depend obviously upon the average load of wagons before palletization.

It is moreover possible that the adoption of palletization by clients will lead, as a result of having regular forms of packing whose dimensions are fractions of those of the pallets, to less voluminous packings, and consequently to a reduction in the density of the loads.

However, the extension of palletization in railway transport is likely to lead to an evolution in the general organisation which will favour the good user of the wagons.

The fact that the pallet considerably reduces the cost of transhipping and storing operations, at the same time as it speeds them up, without doubt will make it possible to give up running certain through wagons with a low or average tonnage.

Mr. DORJEE also reported this possibility, stating in this connection :

« The organization of parcels traffic in » Holland has not been changed in that » respect that the number of groups has » been reduced, which would be the conse- » quence of cheaper and quicker tranship- » ment and by which the number of par- » tially loaded wagons, especially to small » « groups », would decrease. Some such » system is being investigated, together with » the possibility to combine some small » « groups ». »

On the other hand, the facility with which goods can be stacked due to the use of the pallet may also make it possible for the Railway Administrations to store goods more easily on departure and consequently provide or develop for long distance runs with little traffic, through wagons at longer intervals (every other day or three times a week) with a good load.

Owing to these new possibilities which do not appear to have been fully made use of to date, it cannot be concluded that palletization will definitely lead to an appreciable reduction in the average wagon load, nor that long distance traffic can be excluded from internal palletization of the railway.

Moreover, in view of the breaking up of the parcels traffic runs, which has or could be done owing to palletization, through transport over very long distances is not often met with on the railway, except perhaps in the case of very extensive systems as in the United States of America or the Soviet Union.

In fact, it is found that all the Administrations making use of palletization are satisfied with it and agree that it makes it possible to reduce damages and facilitate handling operations whilst shortening them. But above all they are expecting, and in fact are already seeing in many countries, a great development of palletization in industry and commerce in view of the multiple advantages it brings for storing and handling goods, advantages which are particularly great when these operations only concern a limited number of products having standard dimensions.

The very least that the railway can do therefore is to be ready to carry pallets and equip itself for this purpose with suitable handling gear. But many Administrations consider that they should act as « pilots » in the development of palletization.

On the other hand, the dimensions and principal characteristics of their stock (width of the wagons, width of their doors, strength of their floors) are specially suitable for handling loaded pallets whose weight may be some hundred kilos. The additional weight to be carried (pallets and box pallets) is negligible as far as they are concerned from the point of view of its effects upon the cost of the transport.

To strengthen this favourable initial position from the competitive point of view, most of the Administrations are already taking commercial steps to favour consignments on pallets; amongst these various measures which have been mentioned in the two reports, we would stress in particular the setting up of pallet pools.

This is a particularly typical form of co-ordination between the railways and their clients, which favours the interests of both parties.

Thanks to the « pools » the client does not have to bear the cost of returning his empty pallets since the « pool » naturally means exchanges of pallets, number for number.

To avoid any accounts in this connection, it is desirable to assure such exchanges immediately; certain Administrations have made this immediate exchange an absolute rule in their contracts. Other Administrations are more reserved on this point and prefer to be allowed some time for making such exchanges. Immediate exchanges in effect mean that the railway will bear the whole financial burden of the pallets during transport. In addition, owing to the unbalance of the traffic, the railway may fear, if it has not a sufficiently large stock of pallets, that it may experience momentary local difficulties in holding to this agreement.

As far as the technical conditions are concerned, it is obviously necessary for the pooled pallets to be interchangeable, therefore identical. Consequently, in each category of ordinary pallets or box-pallets clients belonging to the « pool » must use pallets identical in type with those of the railway.

To sum up, remembering that palletization may make it possible to reduce and simplify handling operation, we conclude with Mr. Dorjee :

« The principal motives for the introduction of palletization rather seem to lie in the desire to render more attractive the working conditions for the depot staff and in the possibility palletization offers for supplying a link-up with the internal transport of many consigners who have embarked upon palletization or will do so yet. In this respect palletization is the most obvious form of mechanization and it will undoubtedly find further expansion in the near future. »

In the present report we have taken care to deal only with those points which merit being called to the attention of the delegates to the Congress, either on account of the real or apparent divergencies resulting from the replies summed up in the two reports, or because of their importance and their influence on the carrying out of the parcels services.

Many other questions of a less essential character have been passed over in silence, but they have been mentioned in the proposed summaries which we have prepared with Mr. Dorjee and propose as a basis for the discussions at the Madrid Congress.

SUMMARIES.

I. General observations.

1. The relative importance of the parcels traffic differs appreciably from one country to another. It is linked up with the economic and social structure of each country and also, naturally, with the general organisation of its transport.

Each Administration must not overlook such parallelism, as the evolution of these structures affects the parcels traffic and

requires decisions to be reached concerning the organisation and measures of adaptation to be taken.

2. The permanent objective to be aimed at is to improve the parcels trafic both as regards quality (rapidity of transport, no damage, door to door transport, etc.) and costs.

In this connection it is essential :

— to reduce handling operations;
— to mechanise such handling;
— to make good use of the wagons.

3. The « classic » type of organisation into regions and regional centres, based on the advantages gained by the concentration of the parcels at a reduced number of transit points and the making up of long distance through-wagons is adopted by all the Administrations of some importance.

It limits the number of stages and makes it possible, if the regional centres coincide with localities having an important traffic of their own, to transport a large number of parcels directly from the consigning station to the destination station.

4. However, in spite of the adoption of the « classic » organisation, it is impossible for very extensive railway systems — unless they consent to an inexcusable waste of rolling stock — to run through-wagons between all their regional centres. Intermediate transhipments are unavoidable for a certain number of long-distance consignments. It is advantageous to concentrate them into a small number of selected nd suitably equipped points.

It is of advantage if such points coincide with the regional centres.

5. Within the framework of the classic organisation, a free hand can to some extent be given to the stations to run other wagons than regular ones. The conditions under which such wagons are put in operation must be linked up with the length of the runs they have to make: the longer the run the more necessary it is to get sufficient use of such wagons.

This method, which can be used by all the consigning stations, makes it possible to avoid transhipments (transhipment at the centre station of the departure region or even at the centre station of the arrival region).

Certain Administrations use this method in the transhipment stations as well, but the rational use of such wagons then presupposes a preliminary knowledge of the actual traffic :

— either by a preliminary storing of the parcels on the platforms, which involves additional handling:
— or by preparing the work of the depots concerned from the waybills when these are sent with the wagons or by a parcels traffic planning.

6. Certain Administrations use the transport documents to regulate the forwarding of the parcels. Carried out in somewhat various ways, such an organisation makes it easier to :

— determine the cause and responsibility in case of delay, loss or damage:
— organise and control the handling operations.

In other countries, the transport documents are forwarded separately and are only checked against the parcels on arrival. Such an arrangement simplifies and appreciably speeds up the loading and unloading of the wagons at departure or en route.

7. In many countries, the checking at departure and arrival have been considerably simplified in order to reduce costs.

II. Goods depots.

8. In depots where no transhipments take place, it is advisable to have the areas for the handling of incoming and outgoing goods under one roof.

This arrangement makes it possible to reduce the staff required for handling, and facilitates the supply of empty stock (wagons and pallets) to the « outgoing » area.

It may make it possible to deal with seasonal variations in the traffic by extending one area at the expense of the other, or even, exceptionally, provided door to door deliveries are carried out immediately by the delivery service, to use the same area for both purposes : handling at arrival in the morning and forwarding in the evening.

In the interest of the customers, it is desirable to avoid forwarding in separate buildings allocated to different destinations.

9. In stations with a transhipment area, especially in the regional centres, it is advantageous, in order to obtain a greater concentration of parcels, to juxtapose :

— the « transhipment » and « arrival » or « transhipment » and « departure » areas, according to the amount of traffic that can be combined in this way;
— or even, better still, to combine all the areas into a « single depot ».

10. Railway depots must be as far as possible :

— close to the industrial and commercial areas of the towns they serve;
— have convenient road access and a long road frontage which can be extended should the road services eventually be further developed;
— and have suitable connection by rail with the reception and formation sidings for the parcels trains; for this purpose the marshalling yard should be as close as possible to the depots.

11. Most of the depots with small or average traffic are so designed that they have an extensive length and can be served by a single siding, or two at the most.

Large depots, especially those which include a transhipment area must, on the other hand, be planned on compact lines so as to reduce the distance goods have to be conveyed over; they are therefore always served by several sidings.

Arrangements which include dead-end sidings and a platform at right angles to them avoid the operations of conveying the goods and bringing in or taking away wagons interfering with each other.

12. When it is necessary to cross over the sidings to get from one platform to another (as in the case of very long platforms or depots served from both ends), the goods can be handled by going through the wagons, or else, use can be made of flat wagons arranged for this purpose, or finally in the case of large installations, fixed bridges with a movable deck can be used; but with all these methods the handling of the goods is interrupted whilst the wagons are being put into position or taken away.

13. The design, space required and division of the handling areas depend mainly upon the following factors :

— the amount of goods to be handled and the relative volume of the peak traffic;
— the ratio in amounts of incoming, outgoing and transhipment goods;
— the number of destinations over which the traffic is spread and the number of delivery zones;
— the existence of collection and delivery services belonging to or attached to the railway;
— the system of dispatch;
— the method of working adopted with or without mechanisation of handling operations.

14. The most generally prevailing tendency as regards the layout of the different areas in the large depots can be summed up as follows :

— small « consigning » areas limited to the space necessary for accepting, and if necessary, sorting parcels before conveying them to the wagons;
— extensive « arrivals » areas because of the space needed for the storage of the parcels pending delivery.

It should be noted that :

— when goods are collected at the station much more room is needed than when they are home-delivered;

— the space required for the storage of parcels at the end of the week which parcels cannot be delivered because the shops are closed is generally becoming greater and greater owing to the social evolution taking place.

As regards the platforms serving the sidings, their width varies dependent on the mechanisation of the handling and the amount of goods to be put onto the platforms before being loaded into the wagons.

15. The development of mechanised handling makes it necessary to see that there are no obstacles on the platforms and that these have good running surfaces.

In nearly every country the height of the platforms corresponds with that of the floors of railway vehicles (1.15 m to 1.2 m = 3′ 9 3/8″ to 3′ 11 1/4″), so that goods are handled on the same level.

There are difficulties on the road side in every case, since the floors of private lorries and delivery vehicles are at very varying levels.

In order to handle heavy parcels, pallets and small containers, in spite of such differences in level, certain Administrations use fixed bridges or movable ones operated by jacks.

In this connection some standardisation of the different categories of road vehicles would be advisable.

III. Traditional handling.

16. The wheelbarrows, stillages and hand trucks commonly used in the small stations are also adequate equipment in the large depots for all handling of goods of low weight or small size within a limited radius of action.

17. In the large depots, when the goods have to be conveyed over longer distances, it is essential in order to reduce costs, to group the parcels into larger units for internal transport and to mechanise their conveyance.

This is effected by loading them onto power trucks, or on trailers or semi-trailers which are then coupled to tractors. Some countries also make use of overhead or underground traction-chains to which trucks are coupled. Belt conveyors are no longer used to move the parcels in this way.

18. Assembling quantities of parcels for grouped handling generally implies their preliminary sorting per destination.

In the large depots, where the parcels are grouped for many different directions, it is generally necessary to set up several special sorting areas, which involves additional handling.

These operations can also be carried out by making a preliminary simplified sorting of the parcels and by using « distributing trucks », which are in fact mobile platforms running alongside the wagons to be loaded in the yards (depots without platforms).

19. The sorting of parcels can be facilitated :

— in the area in which the wagons are unloaded, by using slat-conveyors or unloading machines;
— in the area where small parcels are sorted, by using conveyor belts.

20. With a few rare exceptions, the special handling equipment is used in particular where heavy parcels are concerned.

In the large depots the movable hoists formerly used for this purpose are being replaced to an increasing extent either by fork lift trucks, or, in the case of very heavy parcels which are not loaded outside the shed by 1 t to 3 t mobile cranes working inside the shed, or large-capacity fork lift trucks.

IV. Handling by means of pallets.

21. When used for moving parcels in the depots the pallet has the following advantages :

— the handling of heavy parcels which is difficult with trucks on account of their inevitable loading height is facilitated;

— the four-entry pallet can be tackled from whatever side;

— the pallet provides a means of storage for the parcels, either by stacking the pallets or by placing them on racks;

— the space taken up by empty pallets is very small.

The use of pallets is therefore extremely advantageous in depots where space is scarce.

22. To be economic, handling and conveyance should be carried out :

— over short distances, by hand pallet trucks on simple rollers or, better still, of the bogie type or by pedestrian-controlled power fork lift trucks;

— in the case of moderate distances (50 to 150 m = 55 to 165 yards) by rider-controlled fork lift trucks;

— for longer distances, by trains consisting of lift trucks and trolleys. The fork lift trucks can then be used as tractors if they are powerful and fast enough.

23. The fork lift trucks have internal combustion engines or electric motors.

The purchase price of the former is lower, but the operational costs are higher. In general, they are faster so that they are likely to be preferred in depots of extensive length; the Administrations using them do not report any serious trouble arising from exhaust gases.

The characteristics of the fork lift trucks depend on the dimensions of the pallets used and those of the vehicles to be served (width of the wagons, width and height of the doorways, etc.)

The load which they can handle is limited by the strength of the wagon floors; it seems to be correct that a load of 1 t is sufficient for most Railway Administrations.

Mention should be made of the use of devices with mobile forks or mobile lift-frames (adjustable or retractable) intended to facilitate the manœuvres of the empty or loaded equipment.

24. Many Administrations would like to be able to buy for their small depots simple low priced hand pallet trucks and stackers, in principle purely mechanically operated.

Improvements to fork lift trucks from the point of view of their dead weight and manœuvrability (radius of gyration, size) are also desired.

25. If the characteristics of the existing wagons are in general sufficient for the evolutions of fork lift trucks, a few improvements might nevertheless be considered in the design of future wagons, such as :

— increasing the strength of the floor;

— increasing the width and, if possible, the height of the doorways.

In this connection interesting trials have been reported as regards wagons with sliding sides.

V. Collection and delivery services.

26. Many Administrations are interested in collecting and still more in delivering parcels.

Sometimes the latter operation is included in the official rates for transport by rail and delivery is often assured either directly or through the intermediary of affiliated companies; if not, the Administrations conclude contracts with private firms in which they reserve the right of control of their services (service-times, charges).

27. It is necessary to synchronise the collection and delivery operations and railway timetables. This is particularly important as regards collecting parcels and the departure of the parcels trains.

As fai as arrivals are concerned, the consequences of possible delays on the railway are mitigated by the fact that there are often two delivery rounds a day in the large centres.

28. The conditions under which goods are transferred to the haulage services are linked up with the delivery methods used.

Most often the parcels are loaded onto the delivery vehicles in the opposite order to that of the delivery round.

In general, the delivery man being the only one who knows the round executes the loading :

- either — usually — by collecting parcels already sorted by the railway staff and put into the bays allocated to the different areas of the town;
- or by calling out the parcels which they have on their documents which are then conveyed by the depot staff from the place where they have been stored to the delivery vehicle.

Exceptionally, the parcels are loaded into the haulier's vehicle in a casual order (which implies the use of sparsely loaded trucks); in this case the depot staff can load the parcels as soon as they come in directly on these trucks, thus reducing the area of covered platform required for arrivals.

On the departure side, the hauliers are rarely required to classify the parcels. This is only done in stations with multiple forwarding areas for different destinations, or when there is only a very limited time to dispatch the parcels in a given direction.

One special case is that of the depots without platforms of certain Administrations; when the road vehicles can come in already sorted, the loads can be taken directly to the wagons.

29. From the technical point of view the haulage vehicles should be able to pick up and distribute heavy parcels, small containers and pallets.

From the point of view of handling operations at client's premises where no platforms are available, the solutions tried : small cranes mounted on the lorries, elevating tail boards, low-loading trailers, etc., are encouraging but not always completely satisfactory.

VI. Palletization.

30. Apart from its use as a method of conveying the parcels within the depots, the pallet can be used to carry goods either during their transport in the wagons (internal palletization on the railway), or throughout the whole transport chain from the premises of the consignor to those of the consignee (general palletization).

General palletization, although it is recognised as the most advantageous, is so far the general practice in only a few countries.

Somewhat more numerous are the Administrations applying internal palletization on their railway or developing it.

However, apart from certain countries where the cost of labour is relatively low, the great majority of Administrations are interested in and have undertaken studies of palletization.

31. Those Administrations who have some experience of internal palletization on the railway, or of general palletization, stress the advantages of the pallet for the transport of heavy parcels or grouped consignments; they are of an opinion that palletization has made it possible to obtain :

- a very marked improvement in the quality of transport (speeding up the dispatch, reducing damage and loss);
- great saving in labour;
- less fatigue for the staff and fewer accidents during handling.

In addition, general palletization enables clients :

- to make savings in handling during the consigning and delivery of goods;
- to facilitate and render the storing of goods more economical;
- to use lighter packing when box-pallets are used.

32. Palletization must be debited with :

- the additional costs due to the purchase of the pallets and the equipment used to handle them, as well as the corresponding maintenance costs;
- the cost of labour for stowing the parcels on the pallets and in the boxpallets, which stowing has to be done with great care;

— the increase in the dead weight to be carried by rail and road;

— any transport of empties.

33. The influence of palletization on the average load of wagons is controversial; many countries still have insufficient experience and the estimates which could be made also depend upon the average load of the wagons before palletization. Certain countries have found that there is a reduction in the average load but consider that this does not lead to any major disadvantage provided the runs are not too long.

It is essential to stack the pallets in order to get good loads.

On the other hand, the use of the pallet may favour a good use of the wagons by making it possible to tranship as well as store economically :

— the reduction in the cost of transhipment operations may make it possible to give up certain traffic by direct wagons of small or average tonnage;

— the easy storing on departure may make it possible to run through-wagons for the long distance services with little traffic at longer intervals (every other day or three times a week) with full loads.

34. The proportion of traffic that is palletizable is high; countries where internal palletization on the railway is the current practice estimate that it can cover 70 % or even more of the traffic.

However, the number of small parcels, light parcels and unpacked parcels as well as their heterogeneity from the point of view of types of packings used gives rise to problems which are being solved :

— either by fastening the loads placed on ordinary pallets (very careful arrangement of the parcels in brickwork fashion, hooping, sticking, adhesive tape, etc.);

— or by using box-pallets.

However, box-pallets are costly and the economic results of palletization are the better, the more simple pallets can be used, which would be facilitated by a rational standardisation of packings.

35. From the point of view of carrying out the railway transport, there should only be a few types of pallets, which should all have the same basic dimensions to make stacking possible.

These basic dimensions result from the interior dimensions of the wagons.

The pallets must be firmly constructed to be able to withstand the numerous handling and transport operations they will have to undergo.

However, in some countries there is a tendency to use more fragile soft woods for simple pallets, owing to the national timber resources.

Box-pallets are generally made of metal and have embedded ridges on top to allow them being stacked. Some are collapsible, but these are more fragile and expensive.

There are three types of open box-pallets :

— rigid box-pallets with V shaped opening;

— rigid box-pallets with collapsible sides;

— box-pallets with removable sides.

Closed box-pallets are replacing with advantage the small containers formerly used both in inland and international services (transport of bonded goods).

36. Palletization has been favourably received by the staff; in particular the staff responsible for loading the pallets has clearly understood that the delicate job entrusted to them relieves the efforts of the staff responsible for handling operations.

37. It is difficult to draw up any balance sheet for palletization, but on the whole those Administrations with sufficient experience of this technique consider that it is economically justified as far as the railways are concerned.

In addition, palletization is a means of considerably reducing handling at a time when in many countries there is difficulty in recruiting staff for work of this kind.

The above Administrations are also persuaded of the value of palletization in the field of the general economy and of the development of this technique in commerce and industry. It is important therefore that the railway, being already in a position to profit from this development by reason of the favourable characteristics of its stock, should strengthen this favourable initial position as regards competition by taking all possible suitable commercial steps.

38. In order to assist consignors who are palletizing their consignments and taking into account the benefits the Administrations draw from this, the latter have introduced a certain number of tariff measures :

— the tare of the pallets is not taken into account in determining the weight of the load to be charged, a weight limit being laid down;

— attractive rates for client's pallets returned empty;

— railway pallets are supplied free of charge or at a small hire.

Some of these advantages are scaled down in such a way as to favour clients using pallets of a type similar to those adopted by the Railway Administrations themselves.

Moreover upper and lower weight-limits have been laid down, on the one hand to take into account the power of the handling equipment and on the other, to obtain a sufficient load.

39. In order to reduce the systematic empty returns of client's pallets all Administrations have set up or are considering setting up pallet pools.

This makes it essential for those concerned to use pallets absolutely identical with those belonging to the railway.

The periods within which the compensation of supply and return must be effected are laid down by agreement. Certain Administrations accept the principle of immediate compensation which, whilst being favourable for clients, also has certain advantages for the railway at times.

40. In view of the development of international traffic, many Administrations are of an opinion that the exchange of palletized loads transported under this regime should be facilitated and even that pools should be set up, in order to reduce the traffic of empty pallets.

This measure would also make it possible to extend the sphere of action and value of the national pools already set up and to facilitate frontier crossings (handling and customs operations). International pools, however, like pools with clients, imply standardisation of the types of pallets used and agreements in this connection are in the course of preparation.

[656 .222 .5]

QUESTION 6.

When changing over to electric and Diesel traction for passenger train services, research of the principles which may lead to a rational and efficient organisation of same.

For this purpose to :

- **work out the social and economic needs and with this object in view, classify the passenger services according to the needs of the populations served, the distances, the volume of passenger traffic and its variations;**
- **fix, for each category, the traffic hours and advisable frequencies as well as the reasonable requirements of the public for comfort and speed;**
- **define the most suitable methods to draw up the timetables (including eventually regular interval train services) : choice of the type of train and rolling stock, fixing the runs,**

by G.F. Fiennes,

Line Traffic Manager, Great Northern, British Railways.

Special Reporter.

Question 6 was the subject of two reports :

Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Union of Soviet Socialist Republics, Viet-Nam and Yugoslavia), by R. Carlier (See *Bulletin* for February 1958, p. 85).

Report (America [North and South], Australia, [Commonwealth of], Burma, Ceylon, Egypt, India, Iraq, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by G.F. Fiennes (See *Bulletin* for February 1958, p. 111).

1. Thanks are due to the Administrations which have furnished information and opinions at such cost in time and thought in reply to the long and detailed questionnaire on Question 6.

2. The Question is concerned with the study of railway timetables and disregards any problem of competition of air, road or sea, so as the pressures of political nature.

The social and economic interests of the population are the criteria put forward, even above the interests of the Railway Administration.

3. These interests expressed in broad principles in a timetable are *convenience, reliability, speed* and *cheapness. Comfort,* although not a characteristic of a timetable, was specifically added to the question.

The change to electric or diesel traction is an opportunity to change timetables for the better.

4. If *convenience* comprises frequency of service and a proper cover of the hours of service required by the population; if *relia-*

bility covers punctuality and freedom from failure; if *speed* means overall speed; if *cheapness* means the lowest economic fare, then electric and diesel traction which can work virtually without intermission at marginal costs for added miles or hours, which run with predictable accuracy and with freedom from failure, which have great powers of acceleration and sustained high speed, which can be conveniently built into multiple-unit trains. — these forms of traction surpass steam.

5. For *comfort* their comparative freedom from dirt and smoke and noise, their capacity to transmit through the train sufficient power to heat or cool and to ventilate are added for good measure.

6. The Administrations clearly recognise the advantages of electric and diesel traction. Every Administration has either completed the change from steam or is in process of undertaking the change or is experimenting with that end in view. No Administration has questioned the necessity for a general change.

7. The use to which Administrations have put the new forms of traction vary very widely; between the country which has a national interval timetable by which one can travel between any two stations once every hour of the hours of service, and the countries which have used the change of traction to accelerate, to make more reliable and to cheapen their service.

8. The choice is governed, of course, very largely by the social, economic and geographical conditions of the country — often indeed by political influences. Countries with dense populations economically advanced can support frequent services. The nub of the matter is that all countries are advancing socially and economically. The habit of travel is growing. Yet in many countries the timetables show a lesser increase in train mileage than in clientèle. The opportunity to improve timetables which arises from the change to electric and diesel traction is also a challenge to do so.

9. Since travel is generally a waste of time the principal task of the timetable is to reduce the interference of the journey with other activities by the convenience of the times of arrival and departure, the frequency and the speed of the service.

10. Except in suburban travel there is no need for a service between midnight and 6.00. The « passenger day » is therefore 6.00 to midnight for departures and arrivals. Within this framework for journeys over six hours there is a logical sequence of preference for, firstly, travel by night with departures not before 19.00 and not after 24.00 hours; secondly, by day with either morning or afternoon left clear of travel. Some countries have recently introduced very successfully travel over long distances in the afternoon and evening by high speed trains.

11. For journeys under six hours, travel by day is preferable. The timetables should again leave morning or afternoon clear of travel.

12. It is possible to trace the development of timetables from single trains in the order of the preceding paragraphs into either groups of trains or a continuous service or finally into an interval service. There is a useful broad division into type of timetable which can be called Group and that which can be called Continuous. A Group time-table is one in which either single trains or a group of trains run at particular times of day leaving long gaps with no service. A Continuous time-table is one in which the trains are spread reasonably evenly throughout the hours of passenger service. By a further refinement they may be spread exactly evenly in which case the service is known as an Interval Service. The last refinement of all is the National Interval Service in which the timetables for all main lines and branches are interlocked in a precise and even pattern. Here there is a clear divergence of policy. Some countries which run enough trains between pairs of points to support a continuous or interval service continue to pre-

fer to run trains in groups. The reasons for this choice are usually international or ship connections or a particular peak demand, and these reasons are often valid. It is, however, possible to allow a particular structure of service to persist after the development of the country has transcended that structure. In these cases the addition to the timetables of individual trains is usually a costly and often an inconvenient solution. A stage is reached when a general revision of the timetable as a continuous or interval service better satisfies the public need and produces great economies in rolling stock and train crews.

13. The advantages of the ultimate interval services are that they are easy for the traveller to memorise — provided that the interval is two hours or less : they promote higher frequencies at a low cost : they enhance prestige by their appearance of good order and good planning : they conduce to punctuality by their standard repetition of a pattern.

14. In brief, the evidence is that the growth of travel has not been matched by greater frequency. A forward policy in this respect should warrant in some cases a redesign of timetables as continuous or interval services.

15. The structure of intermediate stops in a service is a most complex study. Decisions are subject to conflicting demands by the traveller and the Administration. The first principle is that is satisfies both the traveller and the Administration to carry a train load of passengers non-stop to their destination. But, to illustrate the difficulty, this principle conflicts both with the demand for frequency for intermediate towns and with a probable interval pattern. Generally the principle is only applicable to trains added to the normal pattern of either the group or the interval service at the time of the maximum demand.

16. The second principle is that the non-stop run should be as long as possible especially with trains at night, so as to avoid disturbance to sleeping passengers. Stops as far as possible should be grouped at the end of the journey. This principle is also subject to the same difficulty and solution as the first.

17. The third principle is to satisfy the claims of intermediate stations for services from the originating terminal between each other and to the terminal of destination as may appear reasonable — an ad hoc solution which is in effect to abandon Principle.

18. In this matter, of course, the change to electric and diesel traction obscures the abandonment of Principle by offering an overall acceleration between terminals at the same time as extra stops are introduced intermediately. Where the growth of the habit of travel, stimulated by the change of traction, can be calculated to support it, an increase in the frequency of the trains can be used to divide the service, even in an interval pattern, into direct expresses and expresses with intermediate stops.

19. *Reliability* is important as a social need. It is in two parts : freedom from breakdown; and punctuality. The timetable must not promise more than the equipment and its operators can perform. The reasons are self-evident and need no further stress.

20. If travel is generally a waste of time, then *speed* is an end in itself — not maximum speed but overall speed. Again, the principle needs no support in argument except this, that speed as well as being a social and economic benefit for the traveller can be turned in the redesign of timetables into great economies in the use of rolling stock and train crews. It is highly gratifying to have noted in the reports of some countries outstanding performances in speed.

21. In overall speed the number of intermediate stops is an adverse factor. This point has been treated. The length of intermediate stops is another. In general the length of a stop is governed not by the requirements of the traveller but by the

time taken to handle mails, parcels, to attach or detach vehicles of freight, to change engines and by the requirements of the Police and Customs at frontiers. These restrictions on speed should be vigorously scrutinised and reduced.

22. For better *comfort* the principal developments must be :

— firstly, to improve the riding, especially of the motor coaches of multiple-unit trains. In some countries it appears that the track is a contributory cause of rough riding but generally it appears that the design of the motor bogies is at fault. There is a great mass of research going on at the present time and it must be pressed to a successful end;
— secondly, to use seats the shape of which is scientifically designed to reduce fatigue. This principle naturally includes the change from « hard » to « soft » seating which is proceeding virtually universally where it has not already been completed. Again a mass of research is in train;
— thirdly, to abandon the obsolete system of ventilation by windows which drop or slide and to adopt pressure ventilation or air-conditioning;
— fourthly, to insulate against noise;
— fifthly, to improve heating and lighting;
— sixthly, to extend and, often, to simplify the refreshment services;
— seventhly, to extend the number of sleeping berths on night trains;
— eightly, to minimise the traffics other than passengers carried on sleeping car trains.

The change to electric and diesel traction which can provide a virtually unlimited source of energy throughout the train is the opportunity to deal radically with the third and fifth of these.

23. So far this report has been treating main-line services. In suburban services what has been said already generally applies with small obvious exceptions such as ancillary traffics, night trains and sleeping cars. The special problem of the peak services is something apart. It is true that both the discomfort and the cost of the peaks can be temporarily minimised by intelligent timetables with particular attention to high speed, the structure of intermediate stops, the design of rolling stock and of terminals. But in the great cities of the world it is also generally true that a significant improvement in timetables is followed by a more than proportionate increase in suburban travel and indeed by a sharpening of the peak : so that the last state is worse than the first. There does not appear to be a practical solution within the realm of reasonable finance except to resume the struggle for staggered hours of work in which all Administrations except U.S.S.R. have failed so far. Civil and political pressures must be brought to bear. Inducements must be offered in fares and in better services on the fringes of the peaks.

24. In this report and in the reports by Messrs. Carlier and Fiennes in the February Bulletin there is nothing which is new to every country, but something which is new to each of them. Intelligent timetables are the need of all.

SUMMARIES.

1. A passenger service by rail is a great advantage for the population of every country and an absolute necessity for many. The habit of travelling is increasing. The services must be adapted to the development of the public demand, whilst being kept within the reasonable standards of sound management.
2. The principles on which a rational and efficient passenger service is based can be summed up in the words : convenience, reliability, speed, comfort, and cheapness. Within the framework of these principles, the change to electric and diesel traction is a favourable opportunity of re-organising the services for the benefit of both the travelling public and the railway.
3. The capacity to work practically uninterruptedly, the relative rareness of breakdowns in service, the great accur-

acy in running, the high capacity for acceleration and sustained speed, the ease with which multiple unit rakes can be made up, and their great cleanliness are the main advantages of the new methods of traction which allow of the greater application of the first principles above than is the case with steam traction.

4. As a journey is to a large extent a loss of time, one of the main objects of a train service is to minimise this loss, primarily by a judicious selection of the departure and arrival times, and by increasing the number of trains and the average speed.

5. The selection of the departure and arrival times of the trains must give priority to the following two objectives :
   - reduce the impact of the journey on ordinary working hours, and consequently encourage night-time, evening or half-day travel;
   - avoid train arrivals and departures between midnight and 6 a.m.

6. Consequently in the case of journeys lasting more than six hours, considering in turn those routes over which the traffic justifies one, two, three, four ... services a day, the practice followed by the railways shows that it is desirable for the timetables to include in the order given the following trains :
   - a night train leaving between 7 p.m. and midnight;
   - a day train leaving early in the morning (in the case of journeys taking less than six hours);
   - an afternoon train (in the case of journeys taking less than twelve hours);
   - one special high speed train at the time most convenient for those using it;
   - other trains at hours dictated more particularly by the special conditions on the line.

7. If the journey takes less than six hours :
   - the night train will be replaced by an evening train;
   - the day trains will leave at hours so chosen that the whole journey can be made in half a day or less, including a meal.

8. The choice between a train service organised in groups and continuous services spaced out over the day depends upon many factors, in particular the length of the journey and the number of travellers; as the length of the journey decreases and the number of passengers increases, usually the Group services give way to Continuous services, and in the end to Interval services in extreme cases. This evolution is facilitated by the changeover in traction.

9. The Group services are suitable for night services and for trains making important connections (with boat services in particular).

10. An Interval service loses much of its value if the time between two successive trains is more than two hours.

11. The structure of intermediate stops depends :
    - on the amount of traffic between the two terminal stations of the run;
    - on the traffic between the intermediate stations and the terminal stations;
    - on the traffic between the intermediate stations themselves.

12. If there is sufficient traffic, it is right to carry the greatest possible number of passengers between the terminals by non-stop trains.

    Otherwise the need to provide a reasonable number of trains is the prevailing factor and intermediate stops will ensure that sufficient numbers use the trains.

    The changeover to electric and diesel traction makes additional stops that one would have hesitated to make with steam traction more acceptable.

13. As stops during the night disturb the passengers, the number of stops made by night trains should be reduced to the minimum.

14. Punctuality is of the greatest importance. The timetables should not promise more than the equipment and staff can reliably perform.

15. Reduction in the journey time is an important factor in increasing traffic, especially over long distances, and in the case of services by day.

 The changeover in methods of traction produces undoubted advantages in this connection, even if the maximum speed allowed over the lines in question is not increased.

 Such an increase in the maximum speed should only be made after an economic study has been made to ascertain the costs it will involve, the savings it will produce and the increase in receipts which can be expected from it.

 Several Administrations report that the great increases in the average speed obtained in this way have been in general profitable.

16. The use of passenger trains for other traffics, in particular to speed up some of the parcels traffic, is only acceptable to the extent that they do not interfere with punctuality and the structure of the passenger timetables.

17. Service stops must be cut down as much as possible, in particular :
 — on international services by making it the general practice to carry out customs and police checks during the run;
 — on services over lines with different systems of electrification, by using locomotives capable of running on different frequencies and voltages.

18. The efforts of the railways to improve the standard of comfort offered as a rule should be directed to the following points :
 — riding qualities, especially in the case of railcars;
 — heating;
 — sound insulation;
 — forced ventilation and air conditioning;
 — lighting;
 — design and arrangement of the seats;
 — extension of sleeper accommodation on night trains;
 — restaurant services (restaurant cars, buffet-cars and trolley services).

19. In the passenger timetables it is important to study the best user of the rolling stock; good user will make operation more economic, making it possible to deal with a larger amount of traffic with a given amount of stock.

20. Tourist traffic is growing to such an extent that the railways have to cope with considerable seasonal peak traffic. The transport of these large numbers of passengers can only be carried out under reasonable conditions of comfort for the passengers and cost for the railway when the traffic is spread out. Although certain results have been obtained by the Administrations (in particular thanks to reduced rates and special trains outside peak hours), the object in view can only be fully attained with the collaboration of private organisations and above all the intervention of the public authorities.

21. The daily suburban traffic peaks of the great cities put the railways in the same difficulty.

 The changeover from steam traction to electric traction allows the railway to meet further increases in traffic.

 Certain railways report, however, cases in which the possibilities of the new techniques are soon exhausted in their turn. Only a spreading out of the peak traffic, again requiring the intervention of the Public Authorities, can then avoid the need for further heavy capital investment.

4th SECTION — General.

[621 .3 : 651]

QUESTION 7.

Advantage of the use of high speed electronic apparatus for certain administrative work such as :

1) the making out of pay slips;

2) traffic and stores accounts;

3) the checking of the movement of empty and loaded freight wagons, thereby improving the distribution of rolling stock;

4) compiling more rapidly already existing statistics, thus having also the possibility of preparing new ones,

by B.H. DE FONTGALLAND,

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Special Reporter.

Question 7 was covered by the two following reports :

Report (America [North and South], Australia, [Commonwealth of], Burma, Ceylon, Egypt, India, Iraq, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by Sten UBBE (See *Bulletin* for April 1958, p. 435).

Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia), by B. H. DE FONTGALLAND. (See *Bulletin* for May 1958, p. 695).

1. The essential conclusion which must be drawn from the study of the reports concerned with Question 7 is that, at present, the Railway Administrations have very little experience in the use of high-efficiency electronic data processing machines (E.D.P.M.) or « ensembles électroniques de gestion » (E.E.G.).

As is pointed out in the reports, this should not cause surprise, in view of the very recent advent of this type of equipment. But this does not apply to the United States, and we share the regret expressed by the Reporter concerned about the absence of information emanating from the American Railway Administrations.

Even so, a number of Railway Administrations of widely differing importance have already placed an order for an electronic data processing machine (E.D.P.M.) or mean to do so in the near future, and it appears to us that the general description of the working and utilisation of electronic data processing machines contained in the reports and illustrated by examples

drawn from applications in the course of study or already put into practice should provide useful documentation for those Administrations which are at present studying the usefulness of acquiring such equipment.

In view of the new perspectives opened up by it, the question is therefore certainly topical in character. On the other hand, it does not yet permit the drawing of definitive conclusions.

* * *

2. From the user's point of view, an electronic data processing machine may be defined as « *a machine for the automatic processing of information* ». It is common knowledge that complete, accurate and up-to-date information is essential to the management of any undertaking, especially in arriving at decisions. The advent of electronic data processing machines thus represents the introduction of automation into management problems although these machines, up to now, have been primarily developed with a view to solving purely technical problems. Their potentialities in this sphere spring from two basic characteristics :

— their faculty of carrying out operations of logical character, and

— the possibility of storing the working programme in the machine.

Moreover, the very extensive use of electronics permits extremely high working speeds.

Owing to these different features, the potentialities of electronic data processing machines are far in excess of those of standard punch card equipment.

Their practical consequences have been discussed in the reports, and it would seem unnecessary to revert to them. All we wish to emphasize here is the reason why it follows from the very definition of these machines that they can naturally find a wide field of application with the Railway Administrations.

* * *

3. Every undertaking must solve the technical problems in its own field of activity. On the other hand, as far as management or administration problems are concerned, all undertakings, whatever their special activity, have a certain number of problems in common : control of staff and supplies, costing, accounts, budgetary control, financial and investment policy, etc., in addition to the specific problems arising from their particular line of business.

It follows that any equipment designed for management purposes should have the character of a universal tool. This was already true in the case of punch card equipment, and remains so for electronic data processing machines. This is, incidentally, sufficiently confirmed by observing the development of electronic data processing machines in the United States. We were able to conduct an enquiry on this subject in the United States at the beginning of 1957. Already at that time, it was reckoned that several hundred high-capacity and several thousand medium-capacity electronic data processing machines were already in operation or on order, distributed over the most variegated spheres of activity : civil and military government organisations, public services, industry, commerce, banks, insurance companies, transport undertakings (1), universities and research centres, etc. Irrespective of the type of undertaking, the machines were found to be applied to very similar tasks. Among them, the following ones were most frequently encountered :

— control of staff and labour;

— control of supplies and materials;

— issuing of receipts (invoices, insurance policies, dividends, etc.);

— accounts;

— statistics;

— costing;

— budgetary control;

— market research;

— scientific and industrial calculations.

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(1) In particular, the Railway Administrations had 50 electronic data processing machines in use or on order.

We have also encountered, in a certain number of large undertakings, the incipient use of electronic data processing machines as instruments of centralized management (« Integrated Data Processing »), in accordance with the principles outlined in one of the reports.

We recall that, under this conception, the electronic data processing machine constitutes a centralized processing organ on which all the flows of basic data converge and from which all the flows of results relevant to the management of the undertaking emanate. The machine thus becomes a « Management Information Centre », at the disposal of all departments.

4. Let us now revert to the special case of the railways. When analyzing the particular features of the management of a Railway Administration — which has the specific task of conveying passengers and goods — one finds the following salient points :

- a very heavy volume of basic data, be they payrolls of active or retired staff, materials at hand, rolling stock (including motive power units), fares and charges, accountancy items, cost price elements, etc.;
- extreme diversity of statistics;
- a great number of geographically dispersed establishments on which the proper functioning of the services depends : stations, locomotive sheds, workshops, permanent way depots, warehouses, accounts offices, etc.

In confronting these characteristics with those of electronic data processing machines, we find that these machines represent equipment particularly suited to the management problems of railways, provided that the following two conditions are fulfilled :

- The activity of the undertaking, measured in terms of « basic data », must be sufficiently great, which can only be ascertained individually in each case. This was already true of standard punch card equipment, with a relatively low minimum level of activity. This minimum level will no doubt, as a general rule, be higher in the case of electronic data processing machines; but it is relevant to point out that the manufacturers already build equipment of low capacity and moderate working cost so that the use of these machines can be envisaged even in Administrations of medium activity.
- It is essential that the links between the establishments from which the data emanate, the E.D.P.M. by which these data are processed, and the departments using the results furnished by the machines should be studied and put into practice with the greatest care. This requirement is even more important than with standard punch card equipment, because the electronic data processing machines work on the basis of recent data and follow, wherever possible, a daily rhythm; it gives rise to special problems on railway networks organised on a line basis.

* * *

5. A scrutiny of the reports shows that those Administrations which have placed an order for electronic data processing machines have in mind to begin by dealing with management problems not specific to railways :— pay rolls, accounts, supplies control, statistics. In our opinion, this approach appears to be wholly justified since these activities are already most frequently dealt with by standard punch card methods. In contrast, the applications more closely linked with the function of transport, mainly the dispatch of rolling stock and its optimum turn-around (which comprises the redistribution of empty wagons), do not seem to have passed, with rare exceptions, the stage of preliminary study. It is, however, in this sphere that electronic data processing machines are likely to permit, in future, the most worth-while economies. It is known, however, that these problems require careful theoretical studies to which the methods of operational research developed in recent years have made welcome contributions, and we can only wish that

suitable methods will rapidly be developed.

In this connection, and rather beyond the scope of the question, it is interesting to note that certain Railway Administrations have begun to use electronic computers for the solution of problems of scientific character, such as the calculation of timetables. Such problems can also be solved by electronic data processing machines.

Some Administrations also intend to use an electronic data processing machine as a means of centralized or integrated management. In our opinion, this would realize and illustrate to the fullest extent the potentialities of electronic data processing machines. This is a long-term proposition, which must be brought about in numerous stages spread over several years, and which calls, if it is to be successful, for an early re-examination of all the « data flow charts » existing within the system, as a function of its internal organisation. It is, in our opinion, relevant to point out in this connection that such a centralisation of management is by no means incompatible with the decentralisation of command and of executive functions which is indispensable when working a railway. This point is already proved by the fact that numerous Railway Administrations already use standard punch card equipment under similar conditions for the handling of a great variety of problems. Under such a conception, the problem of links referred to above obviously assumes paramount importance, be they « vertical » links within a department for the transmission of data, or « horizontal » links between different departments, at different levels of command, for the utilisation of the results.

The most variegated means of transmission can be used. It would seem that the use of telecommunication methods which require the transmission of coded data over long distances can remain confined to problems where the time factor is essential. In the other cases, for example the movement of rolling stock, it would appear sufficient to forward the data by mail or by night train in the form of punched cards or tapes.

6. In our opinion, therefore, electronic data processing machines appear to be instruments particularly well suited for the solution of numerous problems arising from the management of a railway system, inasmuch as they permit an improvement of present methods and, in particular, open up completely new perspectives, inherent in their original characteristics.

We can even envisage the possibility of applying these equipments to a much larger field, viz. the handling of problems common to several railway systems. Suffice it to recall the growing extent of cooperation between the Administrations in a great variety of spheres : common tariffs, exchange of rolling stock, wagon pools, etc. In each case, it has been necessary to create standard documents. Yet, more often than not, each Administration follows its own methods in processing the same data. For a number of reasons, it even happens that work affecting two Administrations is carried out, identically and simultaneously, by each of them. In our opinion, it would seem to be of interest to study whether, in certain cases, centralized processing by an electronic data processing machine of a problem common to several Administrations would not make it possible to effect substantial economies and to obtain results within a shorter period of time than with the present methods. Such applications obviously presuppose a certain standardisation of administrative methods. Without wishing to conceal the complexity of such a problem, we see in the fact that most of the Administrations concerned are at present studying the use of electronic data processing machines for their own purposes, which necessitates a re-examination of their management methods, a factor favouring the study of centralized management of problems of common interest. It would obviously be desirable to make a start with problems of limited scope which can be handled by electronic data processing machines of medium capacity.

* * *

7. It is obviously much too early to arrive at conclusions concerning the economics of

electronic data processing machines, in spite of certain interesting indications supplied by the reports. We shall however adhere to the distinction, which we regard as essential, between :

— direct economies, i.e. compared with the methods at present in use, be they manual, based on punch cards or, as in most cases, of mixed type. Such economies can be quantified relatively easily as far as it has been possible to prepare a complete programme for the utilisation of an electronic data processing machine beforehand:

— indirect economies, i.e. those resulting from the supply of more exact and more recent information than has been possible by the previous methods so that decisions can be taken on a more scientific basis. Such economies are generally impossible to quantify at the time of the study.

In the United States, we have been able to ascertain that the great majority of the undertakings which have placed an order for an electronic data processing machine take the achievement of indirect economies for granted and regard this expectation as sufficient justification for the acquisition of the equipment. Although, in most other countries, the cost of labour is comparatively lower so that automatic processes do not, prima facie, offer the same financial advantages in all spheres, we think that the positive conclusions in this respect, which have brought about the enormous development of the use of punch card methods by Railway Administrations throughout the world, will find renewed confirmation in the case of electronic data processing machines, again with the proviso of a certain minimum level of activity.

* * *

8. Finally — and this is a topical problem for Administrations interested in electronic data processing machines — the complexity and duration of the preliminary studies must not be under-rated. It is indispensable to organise the research department with great care, to man it with adequate staff in proportion to the volume of applications envisaged, and to give the staff special training, generally with the aid of the manufacturing company.

Team work is an absolute necessity in this sphere since the « data flow diagrams » nearly always exceed the scope of one single department. It is therefore indispensable that the studies are shared by representatives of all the departments concerned who form « Working Teams » comprising a minimum of full-time staff.

We deem is useful to stress the fact that it is preferable to devote a considerable time to the preliminary studies rather than having to revert to these studies at a later stage because the preliminary studies have not been thorough enough; this would have grave repercussions on the financial return of the work.

Similarly, the problems connected with the re-training of clerical and punch card personnel affected by the introduction of an electronic data processing machine must be studied in good time.

* * *

9. In concluding this report, we should like to express the wish that the question of the use of electronic data processing machines by Railway Administrations can be made the subject of a further examination in a few years time when a sufficient number of installations should be in operation to permit the drawing of conclusions based on practical experience.

SUMMARIES.

(1) In view of the extreme novelty of the subject concerned, the summaries outlined below can only have an informative value. A certain number of Administrations, of varying importance, are already using electronic data processing machines (E.D.P.M.) or are engaged in preliminary studies and have placed orders. So far, however, experience is not sufficient to warrant definitive conclusions.

(2) Electronic data processing machines are made up of units which, owing to the use of electronics, operate at very high speeds and have a very high capacity; they are able to carry out any calculation or logical operation (comparison), working from a stored programme.

They are « machines for the automatic processing of information », and their potentialities are far in excess of those offered by standard punch card equipment. In particular, they permit the application of the so-called management by « exception » or « difference » method to problems comprising a considerable number of data or parameters, so that the machines are well suited to serve as instruments of management and, in particular, as a means of arriving at decisions.

(3) Electronic data processing machines thus appear to be suitable for dealing with all the problems arising from the management of a railway system, in particular :

— control of staff and of supplies and materials;

— accountancy;

— statistics;

— costing;

— budgetary control;

— user of rolling stock (turn-round);

— studies of fares and charges;

— technical and scientific calculations (timetable calculations, etc.);

— etc.

(4) The use of an electronic data processing machine appears to be subject to the following conditions :

— a minimum level of activity, measured in terms of « basic data ». The advent, on the market, of electronic data processing machines of small capacity will tend to reduce this minimum level;

— the creation of a suitable system of links between the establishments from which the data emanate, the machines by which these data are processed, and the departments interested in the results.

(5) The applications first dealt with by an electronic data processing machine are, in most cases, those already handled by standard punch card methods. The study of these applications is easier, and economic advantages can be derived from the equipment more rapidly.

(6) The most complete utilisation of the potentialities of electronic data processing machines consists in « centralized management » or « integrated data processing », i.e. the centralized processing of all data contained in the various basic documents in which the activity of the system is reflected, with a view to obtaining from them all the results required for management purposes in all spheres. The electronic data processing machine thus represents a « Management Information Centre », at the disposal of the different departments.

It is important to make the point that such a conception is by no means incompatible with the decentralisation of executive functions which is indispensable in a railway system. Introduction must be gradual and calls, in particular, for a very detailed study of all the information circuits of the system, and for a very efficient organisation of the internal links within the Administration.

(7) Electronic data processing machines appear to be suitable for the handling of problems common to several Railway Administrations : common tariffs, exchange of materials, wagon pools, etc.

(8) As regards the economic aspects, it appears to be necessary to distinguish between :

— direct savings, compared with present management methods, and

— indirect savings, resulting from improved efficiency of management owing to the supply of more exact and more up-to-date information.

(9) Of necessity, the preliminary studies preceding the installation of an electronic data processing machine take a long time and are very complex. They call for an efficient organisation and for specially trained personnel. The best way of dealing with this type of studies appears to be the setting up of « Working Teams », consisting of permanent representatives of all the departments concerned with a particular application.

(10) It is suggested that the question should again be put on the agenda of a future Congress at a time when the Administrations will have acquired sufficient practical experience in this field.

[385 .11]

QUESTION 8.

Financing and conserving railway properties and assets.

Study and comparison for limited companies, partially state-owned companies and State Railways, of the financial means used for the normal renewal of installations and rolling stock.

Forms of amortization and renewal, taking into account for the latter, the slow or speedy depreciation of the currency,

by W. KELLER,

Chef de section du Contrôle des finances et de la comptabilité générale des Chemins de fer fédéraux suisses, Berne.

Special Reporter.

Question 8 has been covered by two reports as follows :

Report (America [North and South], Australia [Commonwealth of], Austria, Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by V. FELDER, Dipl. Eng., Ministerialrat, Finanzieller Direktor der Österreichischen Bundesbahnen. (See *Bulletin* for May 1958, p. 725.)

Report (Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia), by W. KELLER. (See *Bulletin* for March 1958, p. 361.)

The questionnaire was sent to 111 Administrations of whom 41 replied. From these replies it is possible to state — and this is the most striking common point — how much the question of the financing and the conservation of the substance depends upon the legal statutes of the various Railway Administrations and more particularly upon the position of the said Administrations relatively to the State. This is readily explained if we remember that the range of the legal statutes varies from that of the simple operating company owning no assets nor capital proper to the independent undertaking of private ownership.

A second finding of general order : the investment policy of most Railway Administrations is incorporated in or subordinated to the general financial policy of the State. The influence of the State on the financial management and accountancy of the railways is very marked in general.

Before beginning the description of the methods of conservation of the assets and the capital belonging to the railways, the reporter considered it useful to give a brief review of commercial theory and practice. It seems to him that what is good according to science and practice for private industry ought to be also good in principle for the railways. Whether the capital be supplied by the State or by third parties or whether the installations belong to one or the others, in both cases, the capital must be preserved from losses and the productive capacity of the investments must be upheld.

I. PRESERVATION OF THE ASSETS AND OF THE CAPITAL : COMMERCIAL THEORY AND PRACTICE.

In order to produce, the modern undertaking needs to have investments such as machines, installations, buildings, etc. To purchase these, money is needed, that is to say capital. The management of the undertaking has the double task of preserving permanently the substance of its production set-up, and of maintaining in

its integrity the capital invested. This task can only be brought to a good end if the sale prices cover at least the expenses of production, which include both the usual depreciation of the investments because of wear and tear, and from technical progress or market changes. Unlike most of the other costs, the amount of this depreciation does not appear automatically in the books; it must be estimated. This is what is done generally by the amortisations.

As long as money holds its value, the problem of amortisation only consists in evaluating as accurately as possible the period of utilisation of the invested capital and to distribute the total amount of the amortisation over the different years (amortisation on a constant, decreasing, or progressive scale). This total amount was obtained from the purchase value of the investments. If the undertaking should recuperate this purchase value by amortisation, it would be able at the end of the utilisation, either to reimburse the capital or buy a new installation of equal value. In this way, the capital and the substance would be maintained integrally.

But everything has changed through the depreciation, slow or rapid, of currencies which has become the rule in almost all countries. When the purchasing power of money diminishes, the amortisation of the purchase value enables the undertaking to repay the nominal capital at the time the installation goes out of use, but it does not enable it to buy a new one. The nominal capital has been conserved but not the substance. Now the important thing is not the repayment of the capital but the renewal of the plant. The undertaking wants and must continue to exist. This is equally in the general interest of the country and in the particular interest of the investors. These latter have first of all no desire, to be repaid of the capitals invested but rather to be assured of a durable income.

In order that the substance may be conserved in spite of monetary depreciation, the theory has been advanced to proceed by amortising on the replacement cost. By replacement cost must be understood according to the most prevailing opinion, the present day's value, that is to say the value at the moment the amortisation charges are calculated. Theoretically, when the purchasing power of the currency continues to fall, the sum of the annual amortisations calculated on the present day's value remains below the costs of renewal. However, in practice, if the depreciation is not too marked, the amortization amounts calculated on current day values will suffice to ensure the renewal of the investments by auto-financing. This is explainable because, as a rule, all the installations need not be renewed at the same time. Any shortage in the amortisations on the installations to be renewed to-day is then covered by the amortisations of those to be renewed later.

Both in theory and in practice, the amortisation on the replacement value is not admitted universally. It is criticised especially as being inexact and arbitrary. Actually the present day's value of the immobilised capital is not easy to fix. The installations are not like goods with a market price. Rather, they are individual properties, frequently unique, which will not again be reproduced. Moreover, their replacement usually includes some improvement. Steam locomotives for example are replaced by diesel or electric locomotives of greater capacity. If the amortisation charges are based on the costs of renewal of these higher efficiency immobilisations, the simple conservation of the capital would be exceeded. In practice, there is frequently nothing else to do than to calculate the current value by using price indices. Such evaluations however, leave rather a large range to the personal appreciation of whoever makes them.

In commercial practice, the amortisation on the replacement value is not applied uniformly in the different countries. In certain countries, in which money is very much depreciated, the State has permitted the establishment charges to be re-valued. It has in part fixed the price indices to be used for the conversion. In other

countries, in which devaluation has been slower, the fiscal authorities only accept the amortisation on basis of the cost of purchase. In such countries, commercial practice uses other procedures to avoid dispersing that portion of the profits needed to maintain the substance: it applies enhanced rates of amortisation, calculates heavily the amortisations during the earlier years (degressive amortisation amounts), and treats a large part of the costs of renewals as maintenance costs.

To sum up, we find in all countries that industry amortises to the extent needed to conserve its substance by auto-financing. The notion of maintaining the substance is defined widely: it includes not only the replacement of investments by others of equal value, but also their modernisation and their development made necessary by technical progress. Some undertakings finance even great extensions of capacity out of their own resources. To a great extent, it has been due to this auto-financing that the immense development of the productive capacity during recent decades has been made possible, without which, the progress, both technical and social, attained in almost all countries could not have been obtained.

II. CONSERVATION OF THE INVESTMENTS AND CAPITAL OF THE RAILWAYS.

1. Generalities.

The conservation of the substance of the railways is ruled by the same economic laws as those governing industry. It is desirable however to note certain peculiar features.

The problem is particularly important to the railways. Renewal (amortisation) and maintenance represent up to 50 % of the total operating costs. Excessive or insufficient amortisation has important financial repercussions.

Furthermore, fixed installations have a life which is especially long. The permanent way for example is often renewed in details as needed, while other installations, the body of the track and the tunnels, in practice, are never replaced. The depreciation consequently is less apparent and more difficult to translate into figures. Thus the currency depreciation is felt most acutely in the case of installations of a very durable character.

The essential difference lies in the fact that the accounts of most railways are in deficit. Obviously, such accounts do not encourage high rates of amortisation which would only increase the deficits. On the contrary, both the Railway Administrations and the State, which in the end has to meet the railway deficits, succumb too easily to the temptation to « diminish » the deficits by reducing the amortisations or the renewals.

2. The various accountancy methods.

The examination of the replies enables us to state that only a minority of Railway Administrations used the classic method of dealing with amortisation. The majority apply accountancy methods proper to railways. This is partly explained by the special character of the railway installations and their renewal. But it is still more the consequence of the close interdependence which exists between the railway accountancy and that of the State. The following in broad lines are the methods used :—

The most primitive method consists in substituting for *the amortisation charges the actual costs of maintenance and renewal.* This method accepts the annual works of upkeep, maintenance and renewal as compensating the depreciation.

None of the Administrations replying to the questionnaire uses exclusively this procedure. On the other hand, many apply it for specific railway plants such as the substructure, the tracks, the catenary lines, etc.

On the condition that the investments are renewed each year to the extent in which they depreciate, the result obtained

is the same as if the amortisations were based upon the replacement value. Should an Administration owning 25 locomotives, whose average working life is 25 years, and their actual age range from 1 to 25 years, replace each year one locomotive to the debit of the operating account or charge the working cost account with 1/25th of the replacement value of all the locomotives as amortisation, the result is the same in terms of accountancy. This reasoning is based on the fact that on most railway systems a sort of equilibrium is established between the old and the new installations. The average age corresponds approximately to half the useful life of the whole of the installations. As in the example of the 25 locomotives, the depreciation is equivalent to the annual renewal requirements.

The objections to formulate against this method are the following :

The method is only applicable as from the moment when the installations of the whole railway system or a group of installations have reached half their duration of life. For young railways or installations, the charges in the balance sheet would be too low.

If we have said above that the result this method produces is the same as by amortisation upon the current day's value provided each year installations are renewed for an amount equal to the annual depreciation of the whole of the installations, we must however remark : the rates of amortisation can and ought also to take into account a possible reduction in the duration of life technically possible by the coming of new techniques, a change in the habits of customers, etc. The effective renewal of the installations only takes into account on the contrary the actual replacement needs. Referring again to our locomotive example, if the locomotive which has reached its theoretical duration of life is still in good order, it is not replaced by a new one. The balance sheet therefore has not to bear any cost of renewal. Against this, it may be necessary, later on, to replace the locomotives at an accelerated rate, as for example, because of a change in the kind of motive power. The accounts then are burdened with excessive renewal charges, difficult for them to support.

The method reveals itself especially dangerous in the case in which, owing to the bad financial situation, the renewal of the installations cannot be done to the necessary extent; now, this case unhappily is very frequent on the railways. The fact that the renewals have not been adequate cannot be traced in the accounts. On the contrary, the accounts find themselves lightened and give the illusion of an improvement in the financial results.

With a more developed method, the effective expenditures on renewals are replaced in the accounts by the *theoretical charges for renewals*. These theoretical charges are debited to the working costs and to the credit of a corrective account, generally known as « renewal funds », charged to the debit side of the balance sheet. The effective expenditures on renewals are debited to this corrective account. To the credit side of the balance sheet, the value of the first capital investment remains unchanged or fixed : this is why this method is known as the « fixed value » one.

The basis for calculating the theoretical charges is vested in a renewal programme, which in turn is determined by the probable life of the installations and their cost of replacement. Therefore, the same elements determine the calculation of the amortisation on the replacement value. It appears however that the estimation of the life of the investments when calculating the theoretical renewal charges, is based mainly on technical considerations, without taking into account the risks of depreciation due to technical or economical evolution, as is, or ought to be done for the amortisation.

The classic method of amortisation is practised by only a minority of railways. Most of them base the amortisations on the replacement value. In countries in which the investments have been revalued owing to fluctuations of the currency, the values of same, as shown in the revalued balance sheet, are generally used as the

replacement values. The amortisation of the subsequent increases in the assets are calculated either upon the effective purchase cost or upon values revalued by means of price indices. Some Administrations sub-divide the amortisations into two parts, one on the purchase cost, and a supplementary one calculated on the difference between purchase cost and replacement value. This latter assumes the appearance of a provision, suitable for conserving the substance.

3. The notion of maintenance, renewal, and investment in the diverse accountancy methods.

The question of amortisations runs parallel with that of the accountancy of the costs of maintenance, renewal and investment (increases in credit). This accountancy differs according to the method adopted for the amortisations.

When in the balance sheet, the effective expenditures on renewals are substituted for the amortisations, no accountancy distinction need be made between maintenance and renewal on the one hand and the investments on the other. The maintenance and the renewals do not have to be separated since both directly load the balance sheet. The notion of the investment is the same as with the method of the theoretical renewal charges.

The Administrations which debit the balance sheet with the theoretical renewal charges, ought to make a first distinction between the costs of maintenance and those of renewals. The first are immediately brought into the balance sheet. The second, on the contrary, are debited to the « renewal funds » (debit side of the balance sheet), and consequently do not burden the final account. This separation as between maintenance and renewal does not present any difficulties. In most Administrations, it is facilitated by fixing a limit below which all expenditure is, without difficulty, treated as a maintenance charge.

The second accountancy distinction ought to be made between renewal and investment : it is much more problematical than the first. In principle, there is renewal if an existing installation is replaced identically by a new one, and investment if there is an increase in the number of the installations or increase in the productivity of the existing equipment through alteration or replacement by more powerful equipment. In practice, pure and simple replacement is the exception. When installations are renewed, they are improved : the steam locomotives are replaced by electric or diesel motive power : the old wooden four-wheeled coaches are replaced by modern steel or light alloy coaches on bogies; the mechanical signalling installations are replaced by all-electric signal boxes; and so on. How can it be determined in all these cases what is renewal and what is betterment ? Most of the Administrations make the following calculations : a calculation or estimate is made of the cost of replacement of an installation by an identical one, for example the replacement of a steam locomotive by one of the same type. This theoretical cost of renewal is compared with the real cost of the installation replacing the old one, for example the cost of an electric locomotive. If the latter is greater, the difference is considered as an investment and brought into the balance sheet.

In the amortisation method too, it is necessary to distinguish between the costs of the maintenance charged in the operating account on the one part; and the charges for renewal and investment on the other. There is no occasion to make the difficult distinction between renewal and investment, as both are shown as capital charges debited to the account of investments.

4. Rates of amortisation.

In view of the diversity of accountancy methods from both the points of view of the amortisations as from the expenditures on renewals and investments, it is impossible to compare the levels of the amortisations of the different Railway Administra-

tions without making a very thorough study into them. The Reporter has tried however in his first report to do it for some Administrations (see Bulletin Vol. XXXV. No. 3, March 1958).

In this present report, we have to limit ourselves to quoting the limits between which the rates of amortisation of the more important groups of immobilisations oscillate.

The rates of amortisation resulting from the formula :

$$\frac{\text{Value at investment or purchase} - \text{Recovery value of material}}{\text{Duration of use}}$$

is mainly a function of the calculated useful life of the investments. Apart from the value of the recovered materials, generally of no importance, a useful life of 50 years corresponds for example to a rate of amortisation of 2 %.

RATES OF AMORTISATION OR OF RENEWAL.

	%
Railway Installations.	
Lands	—
Substructure :	
Body of the track, including tunnels	0 - 1.5
Structures such as bridges, etc.	0.7- 2.5
Superstructure :	
Ballast	1 - 3
Sleepers, rails, points and crossings	1.5- 4.5
Buildings and fixed installations in stations :	
Buildings	1 - 3
Fixed installations in the stations	2 - 6
Contact line installations	1.5- 4
Telecommunications and signals	2 - 4
Machinery, furniture, stores	3 -100
Rail Rolling Stock.	
Motive power :	
Steam locomotives	1.9- 4
Electric locomotives	2.1- 4
Diesel locomotives, motor coaches and railcars	2.1- 5
Carriages	1.9- 4
Wagons	1.7- 4
Road Rolling Stock.	
Motor buses and lorries	10 - 33 1/3

The relatively low rates practised on most of the Administrations suggest that they base the amortisations mainly on the technically possible life. This life is rather long in the case of railway installations which have to be well maintained for safety reasons. To-day, however, it is no longer enough to maintain the installations and rolling stock in good order. It is necessary for the railway to progress at the same rate as the general development and to follow the example of the competing automobile and aeroplane, it must renew the installations at a higher cadence to remain in pace with the technical progress and the growing demands of the users (travellers and shippers) as regards comfort and speed. The rates of amortisations should take this shortening of the economic life of the installations more largely into account.

5. The repercussions of the state of deficit of the railways on the policy of amortisation and renewal.

The majority of the railways consulted show deficits in their balance sheets. We are not concerned here with the regrettable causes of this state of affairs but only with

the repercussions upon the policy of amortisation and renewal.

If there is a deficit, it is because the working costs including amortisations and renewals have not been covered by the receipts. There is a loss of capital because a part of the money expended did not return to the undertaking, and a loss of substance because the undertaking, being in deficit, sooner or later finds itself unable to renew its investments in the normal way.

In a private undertaking, continued deficits lead to either rehabilitation or failure. This is not the case for the railways, at least for State railways, which are by far the most numerous. The railways are considered as undertakings of public utility. Their deficits are not real losses. They represent rather the counter-value of the services demanded by the State in the general interest of the country but not or insufficiently rewarded by it. The State, which neither wishes nor can renounce these services, is constrained to cover in one way or another the deficits of its railways.

One might be tempted to believe that when deficits are made good by the State, the economic situation of the railways would be restored and would be equivalent to that of an undertaking meeting its own costs. Unhappily this is not the case.

There are few States which assume at their charge the deficit as it shows itself with adequate amortisation. The most often, the State requires that the amortisation or the renewal charges be reduced. It is true that a temporary or reasonable reduction carefully calculated can be justified. It would then be necessary that the reserves of amortisation would have been constituted in good years.

Now, such years are rare with the railways. From these amortisations differently allocated as between good and bad years, usually all that remains is the reduction during the bad years. The temptation to reduce the amortisation is the greater as a reduction of the other charges reveals itself to be much more difficult and painful. Let us only reflect upon the most important cost : the cost of staff.

The enquiry shows that the pressure exerted by the political authorities on the amortisation and the renewal charges in periods of deficit is very strong. There are cases where the normal amortisation, although in no way exaggerated, has had to be reduced almost by a half.

It is self evident that such reduced amortisations do not permit a normal renewal of the installations. In fact, most railways report a more or less marked delay in the renewal and development of their investments.

The arbitrary reduction of the amortisation or renewal charges has another deplorable consequence. It falsifies the accounts and allows the financial position of the railways to appear less serious than it is in fact. As a result, the need and urgency of measures adapted to restore the situation to sound health are not made as clear by the accounts as they should be.

III. SUMMARIES.

1. The great majority of the Administrations replied in the negative to the question if the state of their equipments corresponded to the present state of the technique and to the present needs of the traffic. Very great arrears are ascertained in the renewal and modernisation of both fixed installations and rolling stock.

2. The arrears in the renewal and modernisation of the equipments are explained partly by war damage and the postwar disturbances. But this is not the principal reason. Proof hereof is that private industry has recovered much more quickly than the railways. The main reason lies in the fact that the railways do not have the needed financial means to auto-finance their renewals as is the case with industry.

3. Auto-financing can possibly be done only when the prices cover at least the expenses, these including adequate

amortisations, that is to say amortisations calculated on the economic and not the technical life and on the replacement value.

Now, this condition is not fulfilled with most railways. The amortisations are inadequate, and even these insufficient amortisations are not covered by the receipts. If the amortisations are insufficient, it is not because the Aministrations ignore the harmful consequences which will result. Usually a pressure is exerted by the political authorities on the level of amortisation or renewal charges with a view to reduce the deficits to be met by the State. This pressure explains why the deficits are incompletely covered by the State who so cannot replace sufficient receipts. What the State gives to the railways so far as it meets the deficits is as a rule too much for dying and too little for living.

4. The delay in renewal and modernisation of the investments weakens the position of the railways facing their competitors : for example the railway carriages 40 to 50 years old cannot compete with the modern cars or aeroplanes. Furthermore, it is an obstacle to introduce modern technical methods for increasing productivity and improving the service. The result is a growing deficit which from its side causes a growing pressure on the amortisations.

5. To get out of this vicious circle, the railways ought at least to be able to procure the funds needed for renewing their equipments by auto-financing. This is only possible with adequate amortisations and especially by « earned » amortisations, that is covered by the receipts. To obtain this financial equilibrium, two actions shown to be essential amongst others :

   (1) The railway must be relieved of or indemnified for the costs resulting from the services imposed by the State that favour the economy of the country as a whole; they must also be relieved of charges which are outside the operating needs.

   (2) A reasonable co-ordination must be carried out between the various transport carriers in order to place the railway on equal terms with competing means of transport.

   The question of the conservation of the investments and capital of the railways is therefore fundamentally one of the general transport policy.

6. As regards the accountancy technique of the amortisations and the presentation of the accounts, two things appear advisable : on the one hand, that the Railway Administrations or the Political Authorities, in the event of a deficit, give up the practice of reducing the amortisations below the level materially justifiable and so give a seemingly better appearance to the results; this reduction only serves to hide the real situation of the undertaking and to delay the needed measures of rehabilitation. On the other hand, that the Railway Administrations should follow more closely the commercial practice when calculating and presenting the amortisation accounts. Even if the special methods of the railways were identical materially with the classical system of amortisation, which is only partly true, the adoption of this system would have the advantage of making the railway accounts clear and more understantable by business and political men not specialised in railway accountancy. Accounts difficult to understand give rise to suspicion. Now, the railways need the understanding and the confidence of economic and political circles if they are to make good their claims which can be summed up as follows : to demand prices which cover the costs that is to say which make it possible to conserve the substance and the capital.

5th SECTION. — Light Railways and Colonial Railways.

[625 .143 .3]

QUESTION 9.

Experience obtained concerning the undulatory wear of rails.

— Damaging effects on the track, bridges, viaducts and tunnels, and on the rolling stock.

— Research into the causes of this kind of wear.

— Measures taken to avoid or to remedy it,

by Luis PRIETO DELGADO,

Ingénieur en Chef Adjoint du Département de la Voie et des Travaux,
Réseau National des Chemins de fer Espagnols (RENFE).

Special Reporter.

Question 9 was covered by the two following reports :

Report (America [North and South], Australia [Commonwealth of], Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden and the United Kingdom of Great Britain and Northern Ireland and dependent overseas territories), by N. C. VOGAN. (See *Bulletin* for May, 1958, p. 747.)

Report (Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Union of Soviet Socialist Republics, Viet-Nam and Yugoslavia), by LUIS PRIETO DELGADO. (See *Bulletin* for June, 1958, p. 963.)

Addendum to Report, by LUIS PRIETO DELGADO. (See *Bulletin* for August, 1958, p. 1303.)

The jointly prepared questionnaire was sent to 110 Administrations, 71 of which replied. The Reporter for the English-speaking countries received 22 replies and the Reporter for the French-speaking countries 49. Some of the undertakings who replied, however, stated that they were unable to give any useful information concerning the various questions asked.

To sum up, the two reports were based on the information supplied by the following undertakings, which were able to give more or less extensive information on the questionnaire sent them :

(Report for English-speaking countries.)

Indian Railway Board;
Victoria Government Railways;
Japanese National Railways;
British Transport Commission (Railway Division);
East African Railways and Harbours;
Swedish State Railways;
New Zealand Government Railways;
South African Railways;
Association of American Railroads;
Eire : Coras Iompair Eireann;
London Transport Executive;
New South Wales Government Railways.

(Report for French-speaking countries.)

German Federal Railways;
French National Railways;
Union of Soviet Socialist Republics;

Swiss Federal Railways;
Belgian National Railways;
Belgian National Light Railways Company;
Rhaetian Railway;
Danish State Railways;
Italian Ministry of Transport;
Régie Autonome des Transports Parisiens (Parisian Transport Board);
Netherlands Railways;
Tunisian Railways;
Gafsa Railways;
Algerian Railways;
Czechoslovakian Railways;
Finnish State Railways;
Chemins de fer Economiques du Nord (France) (French Northern Light Railways);
Société Générale des Chemins de fer Economiques (France) (General Light Railways Company, France);
Viet-Nam Railways;
Austrian Federal Railways;
Spanish National Railways (R.E.N.F.E.).

The object of the present report is to sum up the above two reports and formulate the summaries to be drawn from the results of the enquiries made by the Reporters.

* * *

I. General.

As regards the types of undulatory wear, the different types noted may be considered as belonging to one or the other of the following two main groups :

A. — Short wave undulatory wear. The length of the waves varies between 3 and 8 cm (1.181 and 3.149 in.), the most frequent length being 4.3 cm (1.692 in.). The average depth is 0.12 mm (0.00472 in.), reaching as much as 0.4 mm (0.01574 in.) in exceptional cases.

In most cases with short wave undulatory wear there are bright, polished, hard peaks of variable form : continuous projections in the form of a band, longitudinal, transversal, isolated, or sawtoothed humps, double humps or forming as it were a ladder, etc. The hollows are dark, rough, and full of waste from the worn parts. The crests have a martensitic structure. The strain-hardened hollows have a ferrite-perlite structure. This type of undulatory wear sometimes occurs very soon after the rails have been laid and shows a tendency towards a certain stabilisation. In general, it is seen on straight sections and curves of large radius on the main lines of the railways.

Short wave undulatory wear has also been observed in the braking areas, near stations, and wear of the same type on some small radius curves, especially on the secondary railways.

B. — Long wave undulatory wear. The length of the waves varies between 10 cm and 2 m (3.937 in. and 6.562 ft.), with depths of 5 mm (0.196 in.) or more.

The texture of the running surface is relatively smooth, of diminished lustre, and there is relatively little difference between the crests and the hollows. The metal has a strain hardened ferrite-perlite structure on both the crests and hollows. There is no difference between the crests and hollows as regards hardness. This type of undulatory wear often appears as soon as the rails are laid and increases with the age of the rail and accentuated imperfections in laying. It is found above all on lines run over by rolling stock of a homogeneous composition, running at uniform intervals and speeds. This is the case on electrified suburban and urban systems, with passenger train services made up of multiple units.

Long wave undulatory wear may occur on all types of line, on straight sections or curves, on up or down gradients, but usually is found on pronounced curves, of a radius of less than 400 m (20 chains). It is rarely found on main lines with steam traction.

In certain cases of long wave undulatory wear, it is found that the rail as a whole shows the same deformation as the running surface, especially in the case of old rails, those of light section and with certain defects, shrinkage holes, folds in the metal, etc. In general, long wave undulatory wear appears as a deformation under the effects of stresses due to the traffic, affecting in particular any very worn rails, and appears to be a normal form of deterioration. In

small radius curves, the pushing back of the metal is very apparent, especially on the outer face of the railhead opposite the hollows.

Undulatory wear, summarily classified in the preceding paragraphs in reality has many different aspects, and in some cases shows little relation to the established classification. The S.N.C.B. have noted short wave undulations on some lines with bright hollows as well as crests, the whole width of the head of the rail being affected with wear. On the main lines of the U.S.S.R. undulatory wear occurs in the form of long waves, between 0.20 m (7.874 in.) and 2.50 m (8 ft. 2 1/2 in.) long, whereas on the tramway lines the waves are small, between 6 and 8 cm (2.362 and 3.149 in.) in the case of sections built on a concrete foundation, with average sized waves, 10 to 20 cm (3.937 to 7.874 in.) long in sections on ordinary ballast.

No statistics are available concerning the relative extension of the different types of undulatory wear. In some countries, for example South Africa, long wave undulatory wear gives rise to serious trouble; when it attains a depth of 4.7 mm (0.185 in.) the rails have to be replaced to stop the pantographs of electric locomotives coming off the wire. It is however short wave undulatory wear on straight sections or wide curves, especially when it takes the form of isolated humps, that appears to give rise to the greatest inconvenience, affecting the main lines of several railways and making it necessary to grind down the rails. On the S.N.C.F. 20 % of the mileage of the main lines is affected with this type of undulatory wear.

Short wave undulatory wear may affect only one line of rails, or only certain rails of one line, or all the rails of both lines. The fact that the rail is in one or other line does not appear to have any appreciable influence. On large radius curves, it has a tendency to be more clearly noticeable on the lower rails, according to certain observations. On the other hand, in the case of short wave undulatory wear on small radius curves, the undulations appear to be more marked on the outer line of rails, the inner showing continuous wear. The rigidity of laying appears to increase the depth of the waves; in general, the waves are slightly deeper on the inner lines of rails on straight sections of double track, the difference appearing to be due to the greater rigidity of the bed on the side next to the other track.

In the case of long wave undulatory wear, the pseudo-cycle may vary along the same rail. Although it is generally close to the distance between the sleepers, it rarely coincides with the sleeper spacing. On the curves, the most pronounced wear generally is found on the lower rail, though some countries have reported that it is more marked on the outer rail. The opinion has been expressed that it is above all the lower rail which wears, and that the wear is transmitted to the upper rail by resonance. As regards the influence of the radius, the intensity of the undulatory wear increases as an inverse function of the radius, when the radius exceeds 300 m (15 chains) according to measurements made in the U.S.S.R. but in the case of curves of less than 300 m radius, the wear diminishes with the radius; the smaller the radius, the less the wear.

When trains pass noise is set up when the depth of the short wave undulatory wear exceeds 0.08 mm (0.0314 in.). The pitch of the sound produced occurs as a function of the speed and the spacing of the crests. The sound level appears to be influenced by the depth of the undulatory wear and by the penetration of the wheels, the level being greater in the case of wheels of small diameter.

The depth of short wave undulatory wear does not appear to be linked up with the speed of the trains, but rather with the diameter of the wheels and the axle loads. The speed may have a certain influence on the form and position of flaws in the surface of the rails, and perhaps also upon the length of the waves. New South Wales reports that the greater the average speed, the smaller the length of wave.

In the case of certain rails some years

elapse before the first symptoms of short wave undulatory wear occur. In the case of other rails, it is already observed after a few weeks. In the case of premature wear, it would appear that this started when the rails were manufactured. In the case of the same batch of rails, the proportion of rails affected increased with the time they have been in service. The wear may become stabilised or continue to develop; generally, it is not harmful until 5 to 6 years after the first traces appeared.

The forms of short wave undulatory wear are diverse, in relation to the nature of the rail, the place where it is laid and the services over it. Triangular forms have been observed on gradients, an arcaded form on curves, and an isolated and elongated type on straight sections, etc. The development of the wear starts by the apparition of a narrow shiny band along the running surface which develops into indentations with the apparition of bright flaws, and finally results in transversal crests with very hard peaks. The form of the waves appears to be disymmetrical at first. As time passes, evolution occurs in both their form and their position. If the temperature at the surface of the rail reaches sufficiently high values to result in superficial tempering of the crests, the increase in the hardness of the tempered portions increases the amplitude of the waves and at the same time stabilises their position. If this phenomenon does not occur there is stabilisation of the amplitude of the wear at the same time as this moves along the rail in the direction of running. The first form of wear is the most harmful.

As regards the development of long wave undulatory wear, some Administrations have observed that there is uniformity in the waves, connected with the sleeper spacing. The crests arrive in the first quarter of the space between sleepers and the hollows in the last quarter. Other Administrations report irregular development that has no relation to the sleeper spacing. The first indications are highly polished areas at irregular intervals, with a slight spreading of the metal to the outer edge of the rail-head between these high points. Finally, the spreading of the metal becomes more or less general the whole length of the hollows. In some cases the phenomenon becomes harmful very shortly after the appearance of the first signs. New South Wales reports cases of rails laid on small radius curves that had to be replaced after 15 months owing to the very pronounced long wave undulatory wear.

All rails showing undulatory wear still show it after being turned, and all rails without it remain free from it. The waves were more or less formed again after a certain time as a result of the change in the direction in which the trains were running over them.

Rails having a slight specific wear are generally more sensitive to short wave undulatory wear. Such rails rarely show any fatigue cracks; with the exception of heat treated rails, where the waves seem to be the forerunner of general scaling of the running surface. Long wave undulatory wear occurs above all on very worn rails. Such rails are more likely to break, mainly on account of cracks in the compressed metal. Rails laid on a concrete bed have a tendency to break, especially in the web.

II. Influence of the track components.

Rail. — Certain differences in the composition of rails with and without undulatory wear have been noted. It has been observed that certain rails with undulatory wear have a high silicon and nitrogen content. Martin-Siemens rails with a low nitrogen content are generally less liable to short wave undulatory wear than rails made of Thomas steel. The proportions of carbon and manganese have an influence upon the hardness and very hard rails appear to be more susceptible to short wave undulatory wear than soft rails. On the other hand, in the case of long wave undulatory wear, this is more frequent when the rails have a low carbon content.

Heat treated rails (sorbitic and martensitic structures) are more liable than ordin-

ary rails to undulatory wear. This fact can be explained by the difference in the self-tempering possibilities with the two steels; the putting into solution of the carbon takes place more easily in the heat treated rails, in view of their more homogeneous structure to start with, i.e. lower free ferrite content. It appears that the undulatory wear which starts in heat treated rails soon after they are put into service is due in part to lack of uniformity in the cooling, when they are being tempered in the works. Some railways have only found short wave undulatory wear on rails that have been hardened by sorbitization, the running surface of which has been cooled by water spray.

It has been noted very frequently that 25 to 40 cm (9 $^7/_8$″ to 1′3 $^3/_4$″) at the ends of the rails with undulatory wear are free from wear, a fact which can be related to the manufacturing process, as the roller type straightening machines do not work over the ends. It appears that short wave undulatory wear is most likely to occur on rails from large ingots which have to be passed through the rollers several times. The vibrations during rolling are considered to be a probable explanation of certain premature undulatory wear.

Rails from works where the rails are straightened in the flat position suffer less from undulatory wear than those from works where they are straightened upright. In the same way, little undulatory wear has been reported in the case of rails fabricated in works where the rails are cambered hot before being straightened. The D.B. has found that rails which had undergone more extensive straightening in roller type machines showed certain signs of undulatory wear after being laid. Straightening by hammering may leave initial undulations. Any interruption in operation of the straightening equipment may give rise to irregularities spread over the whole length of the rail. Other irregularities can be ascribed to the passage of the rails through the marking presses.

It has not been possible to establish any relation between undulatory wear and the distribution of the segregations.

Short wave undulatory wear affects rails of all weights, but perhaps occurs slightly more frequently in the case of heavy rails. The moment of inertia may have a certain influence, but trials made to influence the vibrations of the rails by making hollows in their profile did not meet with any success. The configuration of the profile may contribute to the variable aspect of the undulations on different lines. Short wave undulatory wear shows itself by periodic variations in the cold-drawing, an increase in the limit of elasticity when cold having advantages, but also the drawback of increasing the phenomenon of self-hardening of the crests.

Long wave undulatory wear occurs more especially as the weight, the moment of inertia and the limit of elasticity are lower. This sort of wear is greater in the case of light rails, whereas short wave undulatory wear tends to affect heavy rails. Some Administrations report that increasing the moment of inertia puts a brake on the development of long wave undulatory wear.

On track laid with long welded rails no special differences have been noted compared with ordinary track as regards undulatory wear. Similar wear is generally observed in the case of rails coming from the same factory whether they are welded or not. It has happened that in the case of two welded rails, one section develops undulatory wear whilst the other is free from it. From these observations, it may be deduced that the nature of each rail plays the decisive part in the development of undulatory wear. As the use of welding is relatively recent, it remains to be seen whether in time the evolution of undulatory wear will be less rapid in the case of lines laid with welded rails. The heating whilst welding of the joints has sometimes caused slight waves near the joint, which may be due to a variation in the hardness.

According to certain observations the use of check rails may lead to a certain reduction in the depth of long wave undulatory wear, especially if there are no joints. Long welded check rails are being tested on the South African Railways. On small radius curves, the check rail may influence un-

dulatory wear by preventing the wheels from sliding. Trials have been made on this point in Austria; the check rails were suppressed on certain curves with serious undulatory wear, but it was not possible to formulate any conclusions as the trial is still too recent. It has been noted by some Administrations that short wave undulatory wear disappears at level crossings fitted with check rails, perhaps on account of the artificial increase in the moment of inertia due to the check rail.

Widening the gauge may perhaps have a certain influence, but in any case the play of the axles of vehicles on the track should be reduced in order to reduce the movement and stresses of the rolling stock on the rails.

Joints. — The parts near joints are generally less subject than the rest of the rail to undulatory wear. Towards the ends of the rails the short wave undulatory wear sometimes becomes irregular, and in certain cases very slight. This effect may be attributed to the process of fabrication, and also to the heat treatment of the ends of the rails. According to observations made by the S.N.C.B., the effect of such treatment is to make the crests appear in the form of a continuous zig-zag. The Victoria Government Railways report that a low joint or one that is welded high results in damping out the waves for about 60 to 120 cm (1′11 5/8″ to 3′11 1/4″) from the joint. A welded or fishplated joint that is properly lined up has no effect upon the regularity of the undulatory wear.

In the case of long wave undulatory wear, near the joints the length of the waves is usually greater than the distance between the sleepers; in the middle of the rail they are usually smaller. Some Administrations agree that fishplated joints favour to a certain extent the development of long wave undulatory wear. The New South Wales Government Railways report that the hollows are deeper above the joint. With staggered joints, the waves are very pronounced about 5 ft. in front of the joint on the opposite line of rails, owing to the oscillations of the electric vehicles.

The behaviour of supported joints appears to be the same as that of overhanging joints using the same type of fishplates. Fishplates that are too rigid vertically act as an anvil under the impact of the wheels, with harmful dynamic effects. The electric trains with their heavy non-suspended masses cause long wave undulatory wear with irregular depressions of the running surface of the rails due to the plastification of the steel, a phenomenon which appears to be connected with the vibration of the wheels when running through a joint.

Sleepers. — No conclusive information has been given concerning the influence of the sleepers. Softwood sleepers of great elasticity appear to cause slightly more accentuated undulatory wear than the more rigid hardwood or steel sleepers. The Victoria Government Railways state that they have carried out trials in which metal sleepers were put on a short section of line with very heavy undulatory wear, and it was found that the waves had a tendency to become damped out on these sleepers.

As for concrete sleepers, as these have only recently been laid, no final statistics are available. According to some replies the use of concrete sleepers appears to be unfavourable on the whole. According to trials carried out on rails from various works half of which were laid on wood sleepers without elastic fastenings and half on concrete sleepers with elastic fastenings, no precise law can be formulated concerning the influence of the type of sleeper and method of fastening.

In the case of short wave undulatory wear, the sleeper spacing does not appear to have any influence. In the case of long wave undulatory wear, the shocks at the joints and the deflection of the rails have an influence and a shorter sleeper spacing appears to be favourable.

Ballast. — Practically no studies have been made on the influence of the ballast on undulatory wear. In general, it is reported that a normal layer of ballast favours the reduction of undulatory effects, but no relation has been established be-

tween the type and size of the ballast and undulatory wear. Rails from the same works laid on different kinds of ballast showed more or less the same amount of undulatory wear. In tunnels, where the layer of ballast is thin and the subsoil hard, undulatory wear is generally slightly more pronounced than on lines in the open air with the normal thickness of ballast. Japan reports that the thicker the layer of ballast, the more frequently undulatory wear occurs.

Formation. — The geological structure of the soil may have an influence, seeing that certain localities are known to be favourable to the development of undulatory wear. Some Administrations report the bad influence of lines laid on a rocky formation in mountain regions. On lines in which the rails are embedded in concrete and run over by multiple unit electric rakes there is a tendency for long wave undulatory wear to occur. The rigidly supported rails of level crossings are also susceptible to long wave undulatory wear. Short wave undulatory wear appears to be less affected by the rigidity of the formation than long wave undulatory wear. Rails with short wave undulatory wear are found on soils of the most diverse nature with very little difference in the wear.

III. Influence of outside factors.

Rolling stock. — The opinion is generally expressed that the evolution of the two types of undulatory wear is affected by the frequence of the trains, but that the depth of the wear is unaffected by this factor. The information supplied disagreed concerning the effect of the speed and volume of traffic. In the case of long wave undulatory wear, the speed appears to have some relation to the length of the waves.

As regards the influence of combinations of factors, such as: method of traction, type of transmission, axle loads, etc., it is generally agreed that these play an important part in the formation of different types of undulatory wear. Short wave undulatory wear corresponds to main lines with high speed passenger and freight trains. The wear develops more rapidly on lines where there is a high proportion of lightly loaded vehicles compared to heavily loaded vehicles. Long wave undulatory wear occurs on electrified and dieselized lines with multiple unit rakes running at frequent intervals with approximately uniform loads. It appears to be greater on lines run over by electric rail motor coaches giving a frequent service at relatively low speeds. In certain cases, increasing the speed and the load results in a sort of polishing of the rails, wiping out the irregularities of the running surface, especially on the outside line of rails.

The dynamic overload (impact) is at its maximum with rail motor coaches, then electric locomotives, empty freight wagons and passenger coaches. It is low in the case of heavily loaded wagons. With low axle loads the wheels give rise to oscillations of great amplitude. With heavy axle loads on the contrary the wheels cause oscillations of small amplitude.

On the main lines no appreciable variation in the classic type of short wave undulatory wear has been noted according to the method of traction, neither as regards the length of the waves, nor the amplitude nor the appearance of this wear. The S.N.C.B. have noted that on electrified lines with very frequent trains the type of short wave undulatory wear with polished crests and hollows occurs.

The uniformity of the diameters of the wheels and their profile, material and type of construction appear to be unfavourable. A small diameter also appears to be unfavourable, especially in the case of heavily loaded locomotive wheels.

The conicity of the tyres plays its part in the elastic torsion of the axles, especially on curves. Carrying axles may cause undulatory wear when their torsional frequency is close to their main frequency of vertical vibrations on the rail.

Ferrodo brake shoes appear to be less harmful than those made of cast iron. The damping out of the vibrations must reduce the high frequency dynamic effects and slow down the formation of undulatory

wear, but so far there are no results nor studies available on this point.

The dynamic effects are the greater as the ratio between the non-suspended masses and the total weight is the greater. The harmful effects of locomotives with nose suspended motors has been remarked upon by several Administrations.

At places where braking regularly occurs, this appears to reduce to the minimum the development of short wave undulatory wear on steam traction lines. On the other hand, with electric traction, braking has a tendency to favour the development of such wear.

On lines at through stations with platforms, even when only a few trains stop every day, long wave undulatory wear is little marked. It is also reduced in stations when the lines are on the straight but braking on curves has a tendency to favour this type of undulatory wear. Near stations undulatory wear is influenced by the braking and accelerating. In general, it is more pronounced in the case of passenger or freight traffic involving frequent accelerations and braking. It is smaller where the trains are running free without tractive effort.

The Rhaetian Ry. reports that on a D.C. line the rail motor coaches having electric brakes working on the rail have not caused any undulatory wear.

On single lines affected by short wave undulatory wear, the type of wear is not so clearly defined as on double lines in which the traffic is always in one direction. On the latter, the humps occur with a slope compared with the axis of the track, whereas they are perpendicular to it on single lines.

As regards the effect of the profile of the lines on undulatory wear, the opinions expressed differ widely. In the case of double lines, the wear appears to be more marked on the down line, perhaps on account of the effects of braking. Some Administrations report that lines run down show less wear than those run up. Short wave undulatory wear appears to be the same on the level and on small gradients on single lines, but to vary on double lines according to the frequence of lightly or heavily loaded vehicles. In the case of long steep slopes, the undulatory wear differs, probably, on account of the braking and skidding of the wheels. With the long wave type undulatory wear, the layout on curves has a definite influence. The effects appear to be particularly pronounced on the lower rail of curves on gradients. Steep slopes involving powerful braking give rise to long wave undulatory wear even on straight sections.

The locality. — Humidity and atmospheric mists appear to favour the accentuation of undulatory wear, according to the observations of various Administrations, whereas others state they have not been able to observe any differences in this connection between the dryest and wettest regions. The behaviour of undulatory wear in tunnels, industrial regions, near the sea, etc., has also given rise to contradictory opinions which remain inconclusive.

IV. Tyre-rail.

Very few observations were made concerning the effect of the wheel upon the rail in the initial stages of undulatory wear, i.e. as regards the causes which have the foremost and greatest effect upon the production of the phenomenon. The opinion generally expressed is that a sort of plastic flow of the metal of the surface of the rail, due to the heavy concentrated pressure, is one of the essential causes of the undulatory wear. High pressures can occur at low speeds on the lower rail on curves with considerable superelevation due to the heavy axle loads (long wave undulatory wear), or again because of a vibrationary state due to the movement of relatively small loads at high speeds, especially on straight sections and wide curves (short wave undulatory wear). Long wave undulatory wear occurs at places where there is an oscillating sideways thrust or skidding of the wheels. This type of wear is increased by an increase in the volume and weight of the traffic.

Small wave undulatory wear also occurs in the braking areas and on small radius curves as several Administrations have noted. The first such wear is probably due to a phenomenon of chattering related to the elasticity of the suspension and the variation in the rail-wheel coefficient of friction when the wheel slides over the rail at variable speeds. The second appears to be due to the fact that it is not possible to compensate by the conicity of the tyres the difference between the two lines of rails, which causes a succession of rolling and sliding movements on the outer rail, probably in relation with the elastic torsions and relaxations of the axle.

Short wave undulatory wear has been noticed on the tyres of certain locomotives, but not very pronounced.

Certain Administrations consider that corrosion accelerates the formation of undulatory wear and causes it to persist, but it has not been possible to find any definite interdependence between undulatory wear and the formation of rust. Corrosion only appears to have a fortuitous influence, by increasing the depth of the hollows which are not touched by the wheels.

None of the Administrations consulted has made a serious study of the progress of the physico-chemical phenomena in the rail as regards the formation and development of undulatory wear and its interdependence with the influences due to the circulation of the trains.

V. Effects of undulatory wear on the permanent way, bridges and viaducts and the rolling stock.

Most of the railways have found that on lines with heavy undulatory wear the permanent way as a whole deteriorates very rapidly : the rail fastenings, coachscrews and bolts become loose, the coachscrew holes become oval in shape, the anticreep devices are pulled out, and the bedding of the sleepers and ballast is upset. The level of the track is rapidly deformed. When elastic spikes are used on rails with serious undulatory wear, it has been reported that a great many of these spikes break in line with the point at which they penetrate the sleeper.

More rapid deterioration of the sleepers is found in areas with marked undulatory wear, which causes an abnormal cutting of the sleepers by the rail. Cases have been reported in which the number of sleepers cut into by the rail is 17 % greater in the case of rails with undulatory wear than on sections where there is no such wear. The life of the sleepers in sections with badly undulated rails is 4 years less than in sections where the rails are free from it. The rapid loosening of the ballast is noted even when the wear is not excessive.

It has been reported that on metal bridges the bolts fastening the longitudinals to the cross stays and the screws rapidly become loose. The bolts sometimes break, but not very frequently. The breaking of rivets and bolts in the connections between the cross stays and transversal beams and other transversal and main beams has been noted; but cannot be attributed with certainty to undulatory wear.

Some railways have noted a sort of undulatory wear on the tyres of wheels. The length of the wave is similar to that on rails with short wave undulatory wear, but the depth is much less.

Researches into its effects upon the rolling stock are very inconclusive. Nearly all the replies agree that the vibrations set up by undulatory wear have a harmful effect upon the various components of the rolling stock : tyres, axle supports, journals, guard plates, springs, brake rigging, non-suspended parts, etc. At the same time the conservation of the rolling stock is improved by proper maintenance of the permanent way and by the adoption of long welded rails. Consequently, it is difficult accurately to estimate the effects of undulatory wear on the rolling stock. Cases of breaks attributable to undulatory wear are very rare, and on the other hand no systematic information is available concerning fatigue and breakages of rolling stock components.

No estimates have been made of the cost of the damage to the rolling stock. It

would appear to be difficult to make such an estimate, as all the trains run over lines on some sections of which there is undulatory wear and not on others. In addition defects other than undulatory wear, skidding, scaling, flaws, defects in level, etc., are all likely to cause serious damage, and it is impossible to isolate any single cause. As for the damage caused to the permanent way, its sum total is estimated to be considerable, and generally all the railways where undulatory wear occurs on a serious scale practise grinding the rails in order to eliminate its effects, and consider such a measure economically justified. The D.B. considers that the damage to the permanent way prevented by grinding would cost a great deal more than the work of grinding.

VI. Measures taken to avoid undulatory wear or to remedy it.

Some Administrations have already taken steps on several occasions to take up rails from straight sections that showed serious short wave undulatory wear and relay them on small radius curves. The existing waves have been ground out by the transversal sliding of the wheels, especially on the inner line, after a few years.

The use of various types of elastic fastenings with rubber bearing plates has not led to a reduction in undulatory wear. There is no type of fastening that can completely prevent such wear, which is essentially dependent on the nature of the metal, but trials have proved the value of having elastic components in the fastening intended to protect the bearing surface of the sleepers where the coachscrew holes have to compensate the play set up by wear in the fastenings and put a brake on the processus of getting out of position. In addition, it still remains to ascertain whether the evolution of the phenomenon can be influenced, seeing that the use of elastic components in the fastening is relatively recent.

Increasing the number of sleepers has a certain beneficial effect as regards long wave undulatory wear, but has no positive results in the case of short wave undulatory wear, according to the observations of several Administrations. The British Railways state that if part of the sleepers are replaced by concrete sleepers mixed in with the wood sleepers, long wave undulatory wear disappears.

Various methods have been adopted for the periodic grinding of the rails in order to avoid the undulatory wear increasing, with satisfactory results in general. However, certain railways report that the waves reappear a short time after they have been ground out in exactly the same positions.

To remove short wave undulatory wear mechanically a technique of planing rails for re-use before they are put in their new position has been adopted, using machine tools with long tables. Likewise « DISKUS » grinding installations have been used. Trials of straightening the rails in a press were found ineffective.

To grind the rails in the track use is made of small movable « RIXEN » type grinders with electric or petrol motors, but special grinding rakes are mainly used with grinder vehicles coupled together fitted with rotating or fixed grinders, or abrasive shoes. These grinding trains, of the Krupp, Schorling, Scheuchzer, and Matisa types, are used with positive results by several railways, to remove short wave undulatory wear. Some railways also grind out long wave undulatory wear every 2 or 3 years.

These measures, combined with renewing old rails, have resulted in 90 % of the main lines being practically free from undulatory wear on some large railways. The quality of the running surface after grinding is as good as that of new rails. In addition there is a considerable improvement in the running surface in line with the joints.

Heat treatment before or after the undulatory wear has formed is not effective. Trials have been made of annealing the surface of the railhead with a blow-lamp on site, and by high frequency processes, in order to destroy the self-hardened layer on the crests. The results are uncertain and the cost higher that that of grinding.

Trials have been carried out of grinding

rails affected with short wave undulatory wear to a depth just below the surface of the hollows and giving them heat treatment. The wear reappeared in the same place in a few weeks' time.

Trials of annealing rails in a tempering furnace before laying them appears to have some effect, but the results are indecisive. In general, methods of reheating the rails have not given any results.

Wear occurs later in the case of rails planed before laying but afterwards continues to increase. Grinding the rails before laying them has been tried recently, but no definite results are available and the profitability of this practice remains to be proved. Trials of grinding a short time after the rails have been laid have given good results, but no comparisons have been made from the economic point of view.

Grinding of tyres is too costly and only a few trials have been made. The tyres are generally reprofiled by milling and turning.

VII. Results of trials systematically carried out.

Certain Administrations have undertaken various trials but most of them are too recent and the detailed study of the information obtained in still in hand.

On the D.B., different types of rails were laid in 1951 on one section of line, from various mills and fabricated according to different processes.

Normal Thomas steel rails with an increased manganese content; normal rails blown with an oxygen rich blast; Martin-Siemens rails, normal or with increased manganese content. Rails of each of these categories of steel were modified by the use of various treatments: usual or excessive straightening in the rollers; straightened by hand press; normal straightening followed by annealing in the furnace and restraightening by hand press; ordinary straigthening by rollers, finally 2 mm planed off.

The results observed were as follows:

1) Certain rails, especially those of Thomas steel, showed pronounced undulatory wear, whereas the Martin-Siemens steel rails, all with a low nitrogen content, remain free from it or only showed slight signs.

2) The effect of increased stressing of the rails by the rollers produces the original waves.

3) The behaviour of Thomas steel rails blown in an oxygen rich blast was similar to that of Martin-Siemens rails.

4) The behaviour of the annealed rails was also good.

On the S.N.C.F., two trial sections were laid in 1951 on lines with differing traffic, at places which always showed intense short wave undulatory wear. In these trials the metallurgical and the mechanical factors were varied.

Metallurgical factor. — Rails of two different profiles in Thomas steel with low nitrogen content; in soft, average and hard steel; in sorbitic treated steel; in martensitic treated steel; in treated steel with preliminary annealing.

Mechanical factor. — One section is welded throughout, the other laid with the usual type of joints. All the different types of rails have been laid in each section; on wood sleepers with bearing plates; with elastic fastenings and rubber plates; on concrete sleepers. In addition, 4 rails that had been given artificial undulatory wear over half their length, some by means of a press, the others by grinding, were laid.

Results. — The method of laying has very little effect upon the tendency towards undulatory wear, but the chemical composition, heat treatment and the method of fabricating the rails have a pronounced influence. Soft or average rails and rails with a low nitrogen content are free from undulatory wear. Hard rails and TT martensitic rails show traces of nascent undulatory wear. The TT sorbitic rails or semi-annealed have characteristic undulatory wear. The artificial undulatory wear on

the 4 rails of average hardness disappeared. The surfaces of the ordinary rails are without defect, whereas those of the TT rails appear to be starting to scale.

The researches carried out by New South Wales Government Railways have as their object :

1) use of rubber cushions between the rail and the sleeper plate;

2) trial of the effect of grinding the undulatory wear and heat treatment of the rails;

3) trial of the vibrations of the vehicles in order to establish if these synchronise with the frequency of the undulatory wear at the site in question.

These trials are still in hand, but the results obtained to date lead to the following conclusions :

1) rubber pads have little effect upon the development of undulatory wear;

2) neither grinding nor normalisation of the surface of the rail can remove all traces of previous undulatory wear;

3) there are no vehicles which vibrate and hammer the track at the frequency of the waves observed in the trial section.

It has been possible to produce undulatory wear in the laboratory, either by rubbing a rail with a steel bar, or on the rollers of an Amsler wear machine. An attempt was made to influence the oscillations of the torsion by artificially creating a gap of 4 mm ($^5/_{32}''$) between the diameters of two wheels fastened to the same axle. The smaller wheel showed definite signs of undulatory wear in its tyre, which appears to indicate that the chattering plays a certain part. All these trials are still in hand.

VIII. Observations upon the results of studies made on undulatory wear.

The experience acquired concerning the wear, or rather the undulatory deformation of rails is insufficient to guide us in endeavouring to ascertain the causes of this type of wear. The factors which come into play are extremely numerous, whether it is question of the influence of the track components or that of outside elements. In general, the opinion is expressed that a type of plastic flow of the metal due to the great concentrated pressure is one of the essential causes of undulatory wear, but a complete explanation of the phenomenon in question is a difficult matter. The influences of the operating, skidding and friction, chattering, vibrations, oscillations of the axles, and the inherent characteristics of the materials of which the rails and tyres are made, the physico-chemical characteristics, changes of condition, oxydation, hammer-hardening, deformation, either overlap or are interdependent. The complexity of the phenomenon of undulatory wear makes it difficult to explain it.

On the other hand, the explanations given by theorists who have carried out studies on the problem in question seem to be as diverse as uncertain. All complex problems dealt with theoretically lose contact with reality, as this cannot be included in all its amplitude in the hypotheses selected somewhat arbitrarily by the theorist, from which he proceeds to reconstruct the facts. This imaginative reconstruction is always a somewhat untrue picture of the reality.

A very brief summary of the opinions of the theorists can be given by grouping together those which only differ slightly :

1) Material of which the rail is made or method of fabrication. Original undulations accentuated after laying, due to rolling defects and defects in the straightening machine. Too great differences in pressure while passing through the rollers and being put through too many times; too high a temperature during the last passage; vibrations on coming out of the rollers; the size of the ingot may be the cause of different welding of the metal during rolling; skidding on the rollers when passing through the straightening machines; irregular cooling; unequal resistance to corrosion and the mechanical wear of the segregated and non-segregated zones; excessive proportions of manganese and nitrogen.

2) Wheel-rail pressure. Plastic deformation of the rail (rolling and upsetting) due to the action of the loads which stress it beyond the limit of elasticity at the rail-wheel points of contact. The gathered metal forms a very hard ridge. The wheel hammers this, rides over it and falls back on the rail, and recommences the phenomenon. The interval between the waves is a function of the malleability of the rail. The vibrations and the shocks are considered to be secondary effects.

3) Vibration of the rail. If the rail is animated by rapid vibrations, the pressure and degree of adhesion at the point of contact undergo variations proportional to the amplitude of the vibrations and of the same frequence. The tangential force at the point of contact remaining constant, the variations in adhesion may show themselves by periodic accelerations and decelerations of the speed of the wheel, and as the mass of the vehicle is unable to follow them, there is a succession of slides. Wear is caused by abrasion and the crushing of the rail by the sliding and by shocks from the wheels.

4) Vibration as a function of the original internal stresses in the rail. The tension inside the railhead determines the frequence of the vibration of each rail. The vibration in the hollows decreases the friction and the wear is greater in the ridges. The internal stress starts during the straightening of the rails.

5) Reactions of the rail wheel system with the influence of the rolling stock. Resonance between the vibration of the wheels and of the rails through the effects of the non-suspended masses. Chemical changes due to the raising of the temperature in the rail-wheel contact area. The influence of the vibration of the axles, not of the rail. Influence of the chemical quality and distribution of the material in the wheels. Influence of the oscillations of horizontal skidding of the axles. Influence of the tipping movement of the bogies when the brakes are applied. The rail-wheel skidding undergoes fluctuations of the same frequency as the periodic vibrations of the load, linked up with certain moments of the elastic deformation of the whole of the non-suspended masses and of the track. The rail becomes deformed and fixes the wear by exceeding the elastic limit under the influence of the dynamic overload. The length of the wave is a function of the vibratory characteristics of the axles. Abrasion is the cause of the undulatory wear, the hollows getting more wear than the crests.

6) Influence of oxydation caused by friction. Oxydation of the surface of the rails through the action of the plastic deformations and the chemical activity they encourage, in the rhythmical process of friction (sliding and rolling), by exceeding the maximum coefficient of adhesive friction. The skidding piles up the products (crests) and the rolling crushes them (hollows). The driving wheels, with high moments of rotation favour the phenomenon. The vibrations are not the cause but the effect of preliminary undulations.

Corrosion combined with the rhythmical bounding of the wheels which removes the humidity from the surface of the rail and heats it up and hardens it by shocks. At the place where the wheel has rebounded again the running surface remains damp and continues to corrode. Influence of the torsion of the axles and driving and carrying wheels, which undergo accelerations and decelerations during these rebounds.

All these explanations, stressing one or other factor in order to reconstruct from the same the process of undulatory wear, are unsatisfactory. In addition, it is very hard to discover the true order of the concurrent causes and which factors act first of all and bring about the intervention of the others. For example, opinions are divided as to whether the vibrations of primordial influence are those of the rails or those of the axles, or neither one nor the other, but both of them secondary. In practice, subjective preference for a given order of causes is of little importance. All

the factors which have a harmful effect must be taken into account from the point of view of the facility or difficulty of fighting them effectively to lessen their effects.

Let us consider first of all the result of the replies to the present questionnaire. There are certain experiences upon the consequences of which all the Administrations are more or less in agreement. But the résumé of the results is still very incomplete, the trials being too recent for final conclusions to be formulated. Amongst all the factors intervening in undulatory wear, the characteristics of the rails and their method of fabrication, the laying and nature of the formation, the traffic and the rolling stock, it can be taken as proved that the most important factor resides in the rail itself. The nature of the metal of which the rail is made implies a predisposition which plays an essential part in the appearance and development of undulatory wear. The influences due to the system of laying the rails are less important. These influences: types of sleepers, fastenings, welding the joints, seat, formation, can contribute to slowing down the evolution of undulatory wear, but by themselves cannot produce it on any given rail. A similar character can be attributed to the influence of the rolling stock, pressure and stresses from the wheels, dynamic stresses a function of the suspension and shock absorption arrangements, effects of the non-suspended masses allowing of a harmful combination of the vertical and transversal vibrations of the axles, uniformity or diversity of the traffic, etc. All these influences may contribute to the development of undulatory wear, but they are not capable of causing it on all types of rails; only those rails already predisposed to it are affected.

From the point of view of an explanation of the causes of undulatory wear, it can be said that this occurs as a function of the predisposition of the rail through the dynamic stresses of the loads, favoured perhaps by the defective elasticity of the track. But the technique of the periodic process which comes into play has not been fully cleared up as yet.

It is difficult to arrive at any precise explanation, even as regards the particular or local aspects of the phenomenon. Generally, every observation made is found to be linked up with more than one possible influence. For example: it is observed that short wave undulatory wear is greater on lines where empty stock is frequently run. This effect may be due to the reduced friction of the wheels on the crests, whereas the loaded stock may cause a grinding effect, but it can also be held that the low loads per axle may contribute to the dynamic effects which favour wear. The influence of electrification upon the accentuation of the undulatory wear has been noted, but it may be considered likewise that it is due to the increased loads and speeds which this brings with it. Light rails are less affected than heavy rails by short wave undulatory wear but the hardness and nature of the metal, the characteristics of the traffic, etc., may also have an influence in the observations made in connection with rails of different weights. The roller type straightening press is the only machine used in the process of fabrication which does not work the ends of the rails, a fact which can be related to the observation that rails affected with undulatory wear often show no signs of such wear at the ends, but there is also the possible influence of the variation in conditions due to the joint.

The conclusions which can be drawn from the trials made are very poor, especially as regards the influence of the rolling stock and laying, in order to be able to give a practical orientation regarding possible measures to avoid undulatory wear or to remedy it. Some of the characteristics of rails which resist wear better are already known, but we have not succeeded in perfecting a type of rail which cannot be attacked by undulatory wear. The practical remedy at the present time is to grind the running surface of rails when the wear becomes greater than 0.2 mm (0.0078 in.) and becomes harmful for the fixed installations and rolling stock, as well as the comfort of passengers.

* * *

SUMMARIES.

I. Types and characteristics of undulatory wear of rails.

1. — The different types of undulatory wear can be classified into two groups :

a) short wave undulatory wear, the length of wave being 0.03 to 0.08 m (1.181 to 3.149 in.) (most frequently 0.043 m = 1.692 in.), and the depth 0.12 mm (0.00472 in.) (maximum of 0.4 mm = 0.01574 in.).

b) long wave undulatory wear, with which the length of wave varies between 0.10 and 2 m (3.937 in. and 6 ft. 6 3/4 in.), the depth being 5 mm (0.196 in.) and over.

2. — The commencement and development of undulatory wear are extremely complex phenomena which it is very difficult to explain completely.

The factors which can have an influence upon undulatory wear are essentially :

a) the material and method of fabrication of the rails;
b) rail-wheel pressure;
c) vibrations of the rail;
d) reactions of the rail-wheel system under the influence of the rolling stock;
e) oxydation due to friction;
f) the rolling stock;
g) the profile of the lines;
h) the kind of traffic;
i) method of laying.

3. — The damage caused by undulatory wear is far from negligible and is worth taking into consideration.

Most of the railways have found that on lines showing serious undulatory wear there is rapid general deterioration of the track, loosening of the rail fastenings, coachscrews and bolts, ovalisation of the coachscrew holes, loosening of the anti-creep devices, disturbance of the bed, sleepers and ballast.

It can definitely be stated that more rapid deterioration of the sleepers has been noted in sections with serious undulatory wear.

4. — Again rapid loosening of the assembly of metal bridges has been noted.

5. — Research work concerning its effects upon the rolling stock is somewhat inconclusive.

In general, the vibrations set up by undulatory wear have a destructive effect upon the various parts of the rolling stock. But it is extremely difficult to evaluate the total sum of such damage, especially in the case of the rolling stock.

* * *

II. Investigation into the causes of undulatory wear.

6. — The composition of the metal plays an important part in the formation of undulatory wear. For example, Martin-Siemens rails with a low nitrogen content are generally less subject to short wave undulatory wear than Thomas steel rails, and heat treated rails are more exposed to it than those which have not been so treated.

7. — Rails that have been treated and those that have been straigthtened upright tend to show more marked undulatory wear.

8. — Although short wave undulatory wear affects rails of all weights (perhaps heavy rails slightly more), long wave undulatory wear occurs the lower the weight, moment of inertia and limit of elasticity.

9. — In general, welded track shows no differences from the point of view of undulatory wear compared with ordinary non-welded track.

10. — Certain observations make it possible to state that the use of check-rails results in a certain reduction in the depth of long wave undulatory wear, especially if there are no joints.

On the other hand, it appears that short wave undulatory wear disappears in line with level crossings equipped with check-rails.

11. — The joints are a disturbing influence, but the data collected being contradictory, it is difficult to state whether they affect the formation or the development of the waves, or both together.

12. — No conclusive information has been supplied concerning the influence of the sleepers. No precise law can be formulated concerning the influence of the material used for the sleepers and the type of fastening. However, it has not been proved that the kind and method of laying the sleepers has no effect on the formation and development of the waves.

13. — It appears from an examination of the replies that a well laid layer of ballast is indicated to reduce undulatory wear. Some very large Administrations have found that there is an unfavourable influence on lines laid on an insufficiently elastic bed, especially as regards long wave undulatory wear.

14. — The following factors favour the the formation of undulatory wear : the non-suspended weight in the case of electric traction, small diameter wheels and uniformity of such diameters, braking by means of cast iron shoes, conical tyres, small spacing between driving axles.

15. — The influence of the profile of the lines cannot be determined, the statements made being too contradictory. This also applies to the influence of the locality : humidity, tunnels, corrosion.

* * *

III. Steps taken to avoid undulatory wear or to remedy it.

16. — None of the existing types of fastenings can completely prevent undulatory wear which is to a large extent a function of the nature of the metal. It still remains to ascertain whether the evolution of the phenomenon can be influenced, since the introduction of elastic components into the fastenings is relatively recent.

17. — Increasing the number of sleepers appears to have a beneficial effect on long wave undulatory wear; this is not so, however, in the case of short waves, according to the observations of nearly all the Administrations.

18. — The practice of grinding the rails must undoubtedly attract the attention of the Administrations, both grinding during maintenance and that practised before putting new rails into service. It should be pointed out, however, that the value of grinding before putting rails into service has not yet been proved.

19. — Heat treatment before laying, by annealing, and after laying, by blowlamp, is very costly. The result of such operations is uncertain.

* * *

IV. Systematic research.

20. — The trials and researches put in hand on small sections by certain Administrations are of very recent date, and it is too soon to formulate any final conclusions. However, the following results may be mentioned :

The chemical composition, heat treatment and method of fabrication have a well determined influence upon the various types of undulatory wear.

Certain rails, especially those made of Thomas steel, show pronounced undulatory wear, whilst rails made of Martin-Siemens steel with a low nitrogen content, remain exempt or are only slightly affected.

The effect of increased stressing of the rails by the rollers produces the original undulations.

The behaviour of rails made of Thomas steel, elaborated with an oxygen rich blast, is similar to that of Martin-Siemens rails.

The behaviour of annealed rails is also favourable.

In places where undulatory wear exists, it has been possible to determine that the vehicles do not vibrate at the same frequency as that of the undulations.

The method of laying has very little effect upon undulatory wear.

Rubber plates have very little effect on the development of undulatory wear.

It has been found possible to reproduce undulatory wear in the laboratory; however, the trials not being completed as yet, it is premature to formulate any conclusions.

[625 .6]

QUESTION 10.

In view of the development of light railways, what are the means to be adopted in order to reduce the operating costs of these railways and what are the resulting basic amendments ?

- **Delimitation of electrification and dieselisation in relation to the traffic, capital costs and operating costs.**
- **Co-ordination between rail and road :**
- **Possibilities of mixed rail-road vehicles and of specialised vehicles for rail or road.**
- **Principles to be followed in regard to investment, in order to improve the returns from the capital available for the transport industry,**

by S. L. Kumar,

Director Research, Railway Board, Ministry of Railways, (India).

Special Reporter.

CHAPTER 1.

INTRODUCTION.

This special report is based on the two reports drawn up in reply to a common Questionnaire on the above subject. The questionnaire was issued to the Railway Administrations or organisations in the following countries :

a) In French : Austria, Belgium and Colony, Bulgaria, Cambodia, Czechoslovakia, Denmark, Ethiopia, Finland, France and French Union, Western Germany, Greece, Hungary, Indonesia, Italy, Lebanon, Luxemburg, Netherlands, Poland, Portugal and overseas territories, Rumania, Siam, Spain, Switzerland, Syria, Turkey, Viet-Nam and Yugoslavia. The report on the basis of replies received was prepared by Dr. Eng. E. Stagni. (See *Bulletin* for August 1958, p. 1215.)

b) In English : America (North and South), Australia (Commonwealth of), Burma, Ceylon, Egypt, India, Irak, Iran, Republic of Ireland, Japan, Malaysia, New Zealand, Norway, Pakistan, South Africa, Sudan, Sweden, Union of Soviet Socialist Republics, United Kingdom of Great Britain and Northern Ireland and dependent overseas territories. A report based on the replies received was drawn up by S. L. Kumar. (See *Bulletin* for July 1958, p. 1081.)

Detailed replies to the questionnaire were attempted by about two dozen Railway Administrations. There was a far better response from the French speaking countries than from the English speaking ones. This lack of response can perhaps be attributed, if not so much to the excessive length of the questionnaire, as to an unsatisfactory or, shall we say, ambiguous definition of the expression « light railway » involved in the question. To this we shall revert later. A condensed questionnaire in English only was prepared and was sent to those countries who either had not responded to the original questionnaire or had expressed their inability to do so owing to the shortage of the technical staff in their organisation. Only one Railway Administration replied to the condensed questionnaire.

It was further noticed on going through the replies received to the questionnaire

that in many cases where the so called « light railways » formed an integral part of the remaining railway network, separate statistics of the performance of the light railways were not being maintained.

The present report covers briefly the following aspects of the question under consideration :

(*a*) General. — Definition of the term « light (economic) railways » and its implications; light railways as secondary lines, their division into categories and the distinction between the light railways and the tramways.

(*b*) Present position of the light (economic) railways. — Their mileage, purpose of construction; their development during the last twenty years; mileage closed completely or partially to traffic and public reactions to their closing.

(*c*) Technical and economic review of the light (economic) railways. — Examination of their constructional features; system of traction, motive power and rolling stock position; signalling installations and operating characteristics and economic data — receipts and working expenses.

(*d*) Economic rehabilitation of light railways. — Present financial position; physical rehabilitation; changes in the system of traction; simplification of operating methods; tariff reforms and adjustments; simplification of the transport documents and the rate structure; reduction in the number of staff to economise on the running costs; reorganisation of light railways in one separate system and criteria for retaining light railways in use.

(*e*) Rail-road co-ordination. — Present position of the rail-road competition on light (economic) railways; inherent advantages of the road transport system over railways; means adopted for meeting road competition; methods suggested for improving railways' competitive position; limitation and regulation of the road transport system and need for a policy of rail-road co-ordination.

(*f*) Co-ordination of investments. — Sources of capital for construction and renewals of railways and roads and desirability of a co-ordinated policy for investments.

(*g*) Summary indicating the present phase of the struggle for survival of the light (economic) railways and improving their future.

CHAPTER 2.

GENERAL.

2.1. *Definition of the term « light railways »*. — According to the Chambers's Technical dictionary a « light railway » is either a narrow gauge line (a line with a gauge less than the standard gauge of 4′ - 8 ½″) or a tramway line which does not run along a public highway. This was, perhaps, not the connotation with those who framed the question under consideration.

In his opening speech, Mr. W. A. VRIELYNCK, President of Section V while speaking at the Rome Session in 1950 on Question XIII regarding « modernisation of the maintenance methods of the permanent way on the light (economic) railways », said (vide *Bulletin* I.R.C.A. for December 1951) :

« As for the light railway, this cannot be distinguished from the ordinary railway either by its profile, its gauge, nor by the speeds reached nor even the frequency of the trains nor the density of traffic. The essential difference, it seems to me, lies in the fact that the trains of the light railways are much lighter, much shorter, that the distances

covered are generally shorter, that such railways are not built as a rule on their own separate foundations, and that there are very few stations at least for the passenger services.

There is moreover a very great difference between the various light railways themselves. Some of them were built in order to develop regions of widely different characters: industrial regions, agricultural regions, or forestry regions. In the case of others, their activities are orientated towards the solutions proper for countries with a very dense population.

The topography of the country also leads to very different methods of working: lines built in mountainous or flat country ».

Then he also said:

« It is an undoubted fact that the secondary lines of the main line railways have — or will have — a tendency to change over to light railways or even in certain cases give place to the omnibus ».

While the questionnaire on the question was being framed, a definition was attempted which would be free from the negative aspects so prominent in the first para of the extract above. A positive approach had to be made. The following definition of the « light railway » was included:

A « light railway » may be distinguished from a normal main line railway by its lower traffic density, by its lighter trains and by the smaller axle loads running on it. Such a railway may have a certain importance from the economic or the political point of view but it is not dependent upon the profile, the gauge or the frequency of the train services.

Candidly speaking, the definition was not quite satisfactory but perhaps the best that could be formulated in the circumstances. And this fact was commented on by some railways to whom the questionnaire was sent.

It would, indeed, be clear from the extract of the speech given above that the speaker was in fact giving an evolution of the functions and even the meaning of the term « light railway ». In its original connotation it implied a line generally laid to a narrow gauge for the development of a country, for the exploitation of its agricultural, forest and mineral wealth or a line generally traversing sparsely populated areas and hilly and difficult regions. Such a line could be distinguished from the ordinary railway lines by its constructional features such as a light track laid generally to steep gradients and sharp curves and worked by locomotives with light axle loads and with light trains. Such a line would start with a few railway stations rather far apart, with simple signalling installations and with economic methods for transporting the gradually developing traffic of the region it served. This traffic at least in the beginning was light.

It is for this reason that in Argentina, the light railways have been called « improving » (developmental) railways. Generally speaking, the effect on the railway on the development of the undeveloped regions of a country was more marked during the latter part of the 19th century and the first quarter of this century but it became less significant with the advent of the car, the bus and the lorry.

2.2. *Light railways as secondary lines.* — With the rapid development of the modern road transport system in many countries, the traffic on their railway lines suffered a serious setback due to the severe road competition. Such lines can then join the ranks of the « light railways ». Here then is an example of a profound change which has come about in the original meaning and concept of the term « light railways ». Some railways would prefer to call such lines (perhaps with greater appropriateness) « secondary lines » with the essential object of distiguishing them from the « light railways » which

were recognisable by their light constructional features. Others would define the « light railways » as those where the economy in operation was the overriding factor or where the volume of traffic was below a certain limit.

The « secondary lines » form a significant proportion of the railway systems in all countries and generally operate under the same rules and regulations and scale of tariffs as are applicable to the ordinary lines which carry heavy traffic, particularly in the field of bulk transport. In many countries, as is clear from the replies received to the questionnaire there exists no clear-cut demarcation between their main and their secondary lines. They therefore indicated that they had no « light railways » as defined in the questionnaire. Consequently the aggregate length of the « light railways » on the basis of replies received does not give a true picture of their mileage.

The secondary lines mentioned above as also many of the main lines have to bear the full brunt of the competition from the road transport system; the struggle for their survival is on. The problem before the Railway Administrations is whether by effecting economies in the number of their employees on the light railways in conjunction with radical modifications in their operating methods these lines can be saved from extinction and can continue to discharge some at least of the functions of a railway line economically and effectively.

2.3. *Division of light railways into categories.* — It would be clear from the above that the original meaning and the functions of the light railways have changed entirely due to the development of the competition from the road transport system. With this fact well understood, it is possible to divide the « light railways » on the basis of the replies received to the questionnaire in the following two main categories:

(1) **Light railways in countries with developing economies.**

In them, the development in all spheres including the road transport system is taking place slowly or rapidly depending on the resources they can muster. There is enough traffic still being generated which can enable the railways and road transport systems with minor adjustments and regulatory measures to coexist successfully. Some examples of Railways which come under this category are:

(i) Argentine Railway;
(ii) Cameroon Railway;
(iii) Ceylon Government Railway (C.G.R.);
(iv) Djibouti Addis Ababa Railway (Franco-Ethiopian);
(v) French West African Railway (AOF);
(vi) Indian Railway (I.R.);
(vii) Mediterranean Niger Railway (Medi-Niger);
(viii) Mozambique Railway.

(2) **Light railways in highly developed countries, particularly in Europe.**

Such railways have to meet serious competition from the road transport system in these countries which has reached a high state of development and are, therefore, face to face with the urgent problems of technical and financial rationalisation for the very survival of their light railways.

These railways can be further subdivided into two groups.

(*a*) Group A includes the secondary lines forming a part of the national railway network in a country and managed generally by the State.

In this group, replies were received from the:

(i) Austrian Federal Railway (Ö.B.B.);
(ii) French National Railway (SNCF);
(iii) Greek State Railway (SEK);
(iv) Italian State Railway (F.S.);
(v) Luxemburg National Railway (C.F.L.);
(vi) Norwegian State Railway (N.S.B.);
(vii) Swedish State Railway (S.J.);
(viii) West German Federal Railway (D.B.);
(ix) Victorian Railway.

(*b*) Group B contains the small lines and sections run by private companies though under some sort of Government control. Replies which came to the questionnaire from this group included the following :

(i) French Departmental Railways. (C.F.D.);
(ii) French Light Railways of the North;
(iii) Italian Ispettorato Trasporti Concessi (I.T.C.) which consists of 42 lines or systems of various companies, many of considerable extent, such as North of Milan Co., the Veneta Co., the Ferrovia Circumvesuviana of Naples, the South East Rys, Calabro-Lucane, Sardinian Rys, etc.;
(iv) Swiss Transport undertakings (U.E.S.T.) consisting of 67 lines or systems operated by different companies.

2.4. *Light railways v/s Tramways.* — While defining the light railway, Mr. Vrielynck referred to it as a railway that is not built, as a rule, on its own separate foundation. This would bring in its ambit the tramways usually carrying urban traffic or in some cases inter-city traffic. From the replies received to the questionnaire it would appear that by and large, the tramways in most countries except those of Europe are worked under special regulations which are different from those for the working of the railways. Such lines are usually owned by municipalities and corporations. One instance of a light railway which runs for the greater part of its length along a public road is the Indian Darjeeling-Himalayan Railway. There may be other cases also. On the other hand in the European countries including some others, the distinction between a light railway and a tramway is not so clear-cut. There are railways which have road sections and vice versa and still others with no permanent way of their own.

CHAPTER 3.

PRESENT POSITION OF THE « LIGHT RAILWAYS ».

3.1. *Mileage of the « Light Railways ».* — As stated in Chapter 2, the mileage of « Light Railways » at present in existence based on replies received does not truly reflect their real length. This is because some of the Railways who have large sections of secondary lines where the traffic has shown a serious decline due to the advent of the road transport system, and which should be appropriately included in the category of « light railways », did not supply the basic information. Even those railways who attempted detailed replies to the questionnaire admitted not having included, for various reasons, all the sections which should be classified as « light railways ».

On the basis of the statistics supplied the « light railways » constitute about 22 % of the total route mileage of the railways in the countries where they exist. Their length category wise is indicated below :

Category	Mileage		
	Standard or bigger gauge	Narrow gauge (less than standard gauge)	Total mileage
1	418	7 095	7 513
2 A	20 952	2 893	23 845
2 B	2 213	2 080	4 293
	23 583	12 068	35 651

Note : Standard gauge is 4' 8 ½".

It would be noticed that whereas almost the entire length of the light railways in category 1 is laid to narrow gauge (i.e. less than the standard gauge), a significant proportion of the light railways in category 2 A is laid to the standard gauge or a broader one. The proportions of the standard and narrow gauges in category 2 B are more or less equal.

3.2. *Purpose of construction of the « Light Railways ».* — The light railways were originally constructed to open up inaccessible and hilly regions of a country, to exploit the agricultural, forest or mineral wealth by providing transport for these products to move to the ports or other important collecting centres and in some cases for political and strategic reasons. In general these lines served regions where besides agriculture, some light industries constituted the other pursuits of the population. As such the movement of the goods traffic was of a much greater importance than the passenger traffic. Most of the lines in category 1 continue to achieve these purposes.

A majority of the light railways in category 2 were laid to meet secondary needs of the small populations of the regions they traversed — secondary in comparison with the needs served by the ordinary lines in their country. They provided passenger services of local interest and in general served as feeders to their main lines thus fulfilling a function useful and indispensable for the country as a whole though not so important for the line by itself. By and large, they did not carry any heavy goods traffic. The road transport system could easily meet the transport needs of the communities served by these secondary lines and its development led to the rapid decline of the traffic on them.

3.3. *Development of the « light railways » in the last 20 years.* — The replies to the questionnaire confirm the view expressed earlier that the importance of the light railways for the development of a country so marked till the thirties of this century became much less significant with the development of the internal combustion engine for use in the road transport. Consequently the percentage increase in the mileage of the light railway during the last two decades has been rather negligible as indicated below.

Category of light railway	Percentage increase in mileage as compared to their present mileage
1	8.5
2 A	0.3
2 B	2.1

Poorer still is the position of the light railways under construction. Under category 1, there are no lines under construction or projected. The aggregate mileage under construction or projected does not exceed a hundred miles under category 2. The Swedish State Railways report a line of about 30 miles length under construction and the I.T.C. (Italy) of about 67 miles.

3.4. *Mileage of light railways closed completely or partially to traffic.* — The complete or partial closing to traffic of light railways was dictated by sheer compulsion of the economic factors. The operation of many of them was rendered unprofitable due to the keen road competition and was for some years sustained by public or governmental subsidies. In some cases for political or security reasons, some rail sections with hardly any traffic had to be kept going. To reduce the continuing operating losses some lines were completely closed down while others were closed partially to traffic. From the replies received the following mileage in each category of light railways has been closed during the last two decades :

Category of light railway	Mileage closed		Total mileage closed	Percentage of the present total mileage in the category
	Partially	Entirely		
1	50	244	294	3.9
2 A	5 245	3 280	8 525	35.8
2 B	—	3 828	3 828	90.0

It would be observed that in the aggregate, since there has been an addition to the mileage of category 1 by new construction to the extent of 8.5 %, the net mileage in this category has increased by 4.6 %. This is due to the fact that, as already explained in chapter 2, the national economy in the countries where this category of railways exists is yet developing. Even though road competition has caused serious inroads in the rail traffic, there is yet enough traffic offering to enable both the rail and road services being maintained.

The loss to the mileage of category 2 A. light railways is serious yet since these secondary lines form an integral part of the national network of the railway systems, they are better able to bear the shock of financial deficits. In many cases, since no separate accounts are maintained for these lines, it is difficult to judge the performance and to assess the losses caused by the working of these lines which, as mentioned earlier, serve as feeders to the main lines.

The heaviest losses in mileage have been suffered by category 2 B lines. In the last two decades their length has been almost halved. Since this category is operated by small companies presumably with the help of public or governmental subsidies or fixed annuities, the financial position of the railway lines which have been closed down entirely must have become completely untenable. Economic rehabilitation must have become impossible to keep these lines in operation and the only way to reduce or eliminate the deficits was to abandon the line and provide alternative road replacement services. The Swedish State Railways have reported that due to the closing down of about 430 miles of their light railways during the last few years, there has been a considerable net gain accruing to the Railways.

A close study of the operating conditions of the light railways leads to the following significant conclusions :

(*a*) The category 1 railways are at a different stage of evolution of the transport system in the countries in which they run as compared to those in category 2.

(*b*) The category 2 railways are less essential for the economic and social well being of the countries concerned. They have been supplanted by the road transport system. As a matter of fact the large number of cars per 1 000 persons of their population is an important pointer to this.

(*c*) The importance of the light railways or more appropriately the secondary lines has rapidly declined in European countries. Their railway administrations are alive to the situation which demands either a radical revision of the existing operating systems or closing down of the line if the former alternative is not feasible.

3.5. *Reactions to the closing down of the light railways partially or entirely.* — In all cases where a light railway has ceased to operate partially or wholly, the existing services have been replaced by road services run either by the railways themselves directly, through their subsidiary companies or by private road transport agencies.

Whether the closing down of a section to traffic was partial or complete, a considerable reduction in the staff and labour forces had to be made by the railway administration. In many cases, the staff were called upon to combine a number of distinct duties in one person. There was a considerable resentment and, in some cases, active opposition by the staff to the amalgamation of duties and discarding of the traditional subdivision of staff into well recognised departments such as Engineering, Transportation or Power.

When a railway line has to be closed to traffic partially or wholly, in almost all countries it is essential to obtain the sanction of the national government. This sanction is accorded after consultation with the local governments and other important interests. In some countries, public meetings are held with the representatives of municipalities and of rural communities to explain to them the compulsion of events which had made it necessary to close down a line to traffic. In spite of this, such steps have been generally opposed by the public for some time in the beginning but soon this opposition wears down as the public begin to recognise that the replacement services are adequate and have not caused any great inconvenience to them.

CHAPTER 4.

TECHNICAL AND ECONOMIC REVIEW OF THE « LIGHT RAILWAYS ».

4.1. *Examination of the constructional features.* — The following features are noteworthy :

(*a*) Total mileage of the « light railways » on the basis of the replies received is about 36 000. The actual mileage is much more (Chapter 3).

(*b*) Narrow gauges predominate in the case of category 1 lines whereas in lines of category 2 A, standard gauge is more in evidence.

(*c*) With minor exceptions, flat footed rails are generally used. In narrow gauge lines, the rail weight varies from 24 to 66 lb. per yard. On standard gauge lines and on bigger gauges, the rails weigh between 50 to 72 lb. per yard.

(*d*) On narrow gauge lines, particularly those traversing hilly regions, the gradients are heavy and curves sharp. Though on one narrow gauge railway curves as sharp as of 50 ft. radius exist, generally the minimum radii on most sections vary between 100 ft. and 300 ft.

On standard or bigger gauge sections the minimum radii are rarely less than 600 ft. though very much easier conditions exist in plain sections.

As for maximum gradients, there is nothing steeper than a 3 % on standard gauge lines but on narrow gauge lines without artificial adhesion (rack, etc.), they may be as much as 6 % or even 7.3 % (Bernina Ry.). With artificial adhesion they soar as high as 12.5 % on some Italian sections and 30 % on the Jungfrau section (Switzerland).

By using light rails, sharp curves and steep gradients the engineers who constructed the category 1 lines were able to achieve economies to the extent of about 20 to 30 % in the initial cost.

(*e*) In general, treated wood sleepers of oak, chir and deodar are in use on light railways. In fact on some sections, serviceable sleepers removed

from standard or bigger gauges are used in narrow gauge lines after reconditioning. The exceptions to the use of wood sleepers are provided by French West African, the Cameroons, the Franco-Ethiopian Rys. and on many sections of the U.E.S.T. system (Switzerland) where metal sleepers predominate. The number varies from 2 000 to 2 600 per mile.

(*f*) On most of the light railways the maintenance methods, generally manual, are very similar to those prevailing on their ordinary lines, though the number of gangmen per mile is reduced. Mechanisation such as in drilling of holes in sleepers and tightening of coachscrews has been introduced; on some small systems in Europe mechanical tampers are being tried out. Welding of rails by thermit or arc welding is becoming popular and is able to achieve economies by reducing maintenance as well by permitting use of old rails by reconditioning.

4.2. *System of traction, motive power and rolling stock position.* — Of the light railways in category 1, the Franco-Ethiopian, the Cameroons, the Mediterranian Niger and the A.O.F. have complete dieselisation. Other railways in this category continue to work their trains by steam locomotives. Some diesel locomotives are, as an experimental measure, going to be tried on some light railways in India. In most of the railways coal is easily and more cheaply available, in others the investment on diesels for light railway operation is not considered justified.

In category 2 railways, steam traction is being gradually replaced by diesel traction but as yet there are hardly any sections which have been completely dieselised. Electrification is in most cases not justified as the volume of the traffic offering does not justify the high initial outlay of capital which electrification involves. On the light railways in Switzerland, Austria and on some sections in Italy and Belgium electric traction is, however, widely used. Swedish State Railways have motorised their passenger services by the use of railcars and run their goods trains by diesel locomotives on some of their light railways; whereas steam traction holds its own on some sections.

Very few railways which have steam traction have introduced modern steam locos; many of them are quite old. The axle loads in the case of narrow gauge lines vary from 4 to 9 t and in case of others 11 to 16 t.

The diesels in use on the light railways have axle loads varying from 13 to 16 t on the standard gauge sections; the most frequent type being BB with mechanical or electrical transmission. The locomotives are quite modern in design with the installed power varying between 550 to 850 HP. It is interesting to observe that the purchase price of the locomotives per ton weight or per horse-power shows a certain amount of uniformity.

Among the railcars, there is a far greater variety of designs and wheel arrangements though horse power generally varies between 130 and 450. Standardisation is not possible as these cars have to fulfil quite a variety of requirements under different local conditions. It is perhaps for this reason that there is a great deal of disparity in the purchase price of these cars in terms of their horse power. Generally they cost more than locomotives. Precise comparison between the prices of locomotives and railcars in different countries is, however, impossible and of no great value because of the fluctuating rates of exchange and the widely varying requirements they have to meet on different railways.

Railcars (diesel or petrol) are also in use for passenger services on some light railways where the normal mode of traction is yet steam.

The rolling stock, both passenger and

goods, on the secondary lines is the same as is used on the ordinary lines.

Maintenance of the locomotives and the rolling stock is done on mileage-cum-period basis according to fixed schedules. Running maintenance is carried out in sheds and depots while major overhauls and repairs are undertaken in workshops. Where tyre wear is high on account of sharp curves and heavy braking, frequent turning of the tyre is needed. Some diesel locomotives have been provided with flange lubrication with a view to reducing wear.

4.3. *Signalling installations and operating characteristics.* — On most of the non-European light railways, particularly in category 1, the signalling installations are simple; in general hand operated semaphores are in use. A station may have only one stop signal at each end and, in fact, some stations cannot boast of any signal. Almost all stations where signals exist are non-interlocked. Trains are worked generally on the absolute block system with « line clear » paper tickets, though on some sections one-engine system is in vogue.

Such simple signalling installation and methods of operation are quite suited to the speeds of trains. On narrow gauge sections goods trains run at speeds between 7 to 20 miles per hour and passenger trains between 10 to 20 miles per hour, depending on the topography of the country they traverse. On broader gauges speeds up to 25 m.p.h. are attained.

On the category 2 railways of Europe where passenger traffic generally predominates or where diesel locomotives are in use, the speeds of the order given above would be uncompetitive. On standard gauge sections speeds touch 60 m.p.h. though on narrow gauge lines they may reach 50 m.p.h. except, of course, on hilly railways where the maximum speeds vary between 25 to 35 m.p.h.

With a view to achieving maximum economy in train operation, the system called « single traffic regulator » is in vogue on many secondary lines in Europe. In this system, traffic movement control is concentrated at one station where the single regulator operates. This obviates the necessity of having operating staff at other stations. On category 2 lines particularly in Italy, France, Austria and Sweden there are many stations without any staff at all.

Except on certain category 2 B lines in Italy and Switzerland where very heavy passenger traffic has to be moved, centralised control of the points and the signals (C.T.C.) is not much used.

4.4. *Economic data — receipts and working expenses.* — Most of the reporting railways do not maintain separate operating statistics as also those for the working expenses for their light railway sections. Others who do so have sent such incomplete information that it is almost impossible to make any comparisons of the performance in different countries. However, the data supplied, albeit incomplete, makes some interesting comparisons possible between lines and systems in different countries.

Some of the significant points are set forth below :

(*a*) On category 1 lines, goods traffic plays an important role whereas on the category 2 lines it is generally the passenger traffic which predominates.

(*b*) The law of diminishing costs so characteristic of the railway operation is discernible. For example, on the North Milan line in Italy the passenger traffic is very heavy whereas it is less on the other secondary lines in that country. This is clearly reflected in the cost per passenger mile.

(*c*) Category wise, there is generally a certain amount of parity in the fixed costs per mile as well as in the dependent ones.

(*d*) The tariffs particularly for goods traffic appear to be below the marginal costs. This difficulty can be overcome by raising them on sections where heavy transport vehicles are not yet in the field and road networks are not yet fully developed as for example on some African railways or as on the A.O.F. where effective rail-road co-ordination exists. Elsewhere the salvation lies in reducing the operating expenses.

(*e*) The passenger tariffs on railways are in general appreciably lower (except in Switzerland) than the average bus fares. Thus within limits the tariffs can be increased.

(*f*) On category 2 lines where passenger traffic brings in most of the receipts, it is observed that the receipts are lower than the fixed costs. This raises the issue whether it is worthwhile investing additional capital in modernising the lines with a view to improving their operation.

CHAPTER 5.

ECONOMIC REHABILITATION OF LIGHT RAILWAYS.

5.1. *Present financial position.* — Barring a few lucky exceptions, the financial position of most of the light railways is far from satisfactory; they show heavy deficits. This is more particularly true of railways in category 2 B where deficits are frequently being made good either on the basis of the actual balance sheets or are compensated by giving a fixed annual subsidy. Each of these two systems has its merits and demerits but the former method would tend to make railway administrations negligent about reducing their losses by introducing radical measures for economical operation.

In this chapter it is proposed to discuss the measures which the railway administrations in charge of light railways are adopting or have adopted already for improving their operating balance sheets. These measures are either of the nature of the reorganisation of their services or refer to operating and technical improvements inside their own organisations independent of any steps relating to rail-road co-ordination or for mitigation of the competition from the road transport undertakings.

5.2. *Physical rehabilitation.* — On category 1 railways generally and in some cases in category 2 B railways, the resources are limited for effecting important technical improvements to the track structure (exception C. G. R.) and for providing modern installations for accelerating the services. Whatever capital is available is being utilised for the most pressing needs or the most profitable investments. A few railways (A. O. F., Cameroons, etc.) have provided for mechanical equipment for the track maintenance and a fewer still for improved signalling and shunting installations. Some lines of the C.F.D. and I.T.C. have programmes of modernisation of their assets.

5.3. *Changes in the system of traction.* — Most of the railway administrations particularly in category 2 are of the view that diesel traction is most suitable for the operation of the light railways and they are gradually changing over to diesel traction although barring a few African Railways, none is completely dieselised yet. Dieselisation and provision of railcars of the improved types requires considerable capital outlay but in many cases this investment is financially justified on category 2 railways. Thus S.J. railways report that an outlay of 7 million sterling for dieselisation of a section would bring a financial gain of about a million sterling annually. Many railways in category 2 have already increased their earning capacity by partial dieselisation. Most of the category 1 railways barring those already gone over to dieselisation (A.O.F., Medi-Niger and Cameroons) are not thinking of dieselisation at this stage. Experience has shown that steam traction should be retained where :

(*a*) local supplies of coal are abundantly available and oil has to be imported (Indian Railways and South African Railways);

(*b*) diesel locos and railcars along with their spare parts have to be imported involving the use of foreign exchange;

(*c*) the financial resources are limited and the available capital cannot be diverted to light railways for dieselisation, there being other more pressing needs or better investments;

(*d*) one man driving of a diesel is not feasible due to opposition from the staff or their unions;

(*e*) the traffic potential is less than the line capacity (category 1 railways generally);

(*f*) the factor of weight of traffic moved is more important than the speed (category 1 railways generally).

On the other hand, diesel traction is more advantageous than steam where:

(*a*) the lines capacity is limited in comparison to the traffic offering;

(*b*) due to local conditions (greater lead from collieries, import of coal) oil fuel works out cheaper for rail traction than coal;

(*c*) supplies of water for steam locos is scarce or of bad quality (Cameroons);

(*d*) adequate transport is not available for the movement of coal; oil requires about one third the number of wagons;

(*e*) acceleration of services is vital for meeting the road competition or for reducing the operating costs (category 2 railways generally);

(*f*) better availability of the diesels can actually be realised. Some railways in category 1 have been unable to achieve this to the extent claimed.

Electric traction is normally not justified on the light railways on account of the low traffic offering but it is so where:

(*a*) on account of heavy traffic to be carried, high initial outlay is justified (North of Milan, Circumvesuviana);

(*b*) on account of high cost of oil, electric traction becomes more economical (Italian Rys.). Compared with electric traction, diesel traction shows a slightly higher operating cost but it shows a saving in the annual interest and depreciation charges due to the lower capital cost;

(*c*) on account of the topography of the country (steep gradients and sharp curves), it is necessary to have high tractive effort coupled with a reduced weight of the locomotive (U.E.S.T., mountainous sections of the I.T.C.);

(*d*) a light railway forms a part or serves as a feeder to a small railway system already electrified. Here, uniformity of service and better utilisation of traction units makes for an overall economy if the light railway is also electrified (U.E.S.T., Ö.B.B., I.T.C. and also scheme for electrification of Cancello-Benevent lines).

5.4. *Simplification of operating methods.* — Operating methods have been simplified with a view to reduction of the staff by the use of the single traffic regulator on many category 2 railways and considerable economies have been effected. On a suburban line near Naples it is proposed to install C.T.C. and on many other lines (such as Cancello-Benevent) a system known as « mechanised regulation » has been installed for accelerating the services without affecting safety. Automatic control of signalling installations at level crossings and elsewhere are envisaged by the French C.F.D. and some sections of the I.T.C.

5.5. *Tariff reforms and adjustments.* — An analytical study of the operating statistics of the light railways, particularly of category 2 brought out (Chapter 4) that tariffs appeared to be below the marginal costs and that passenger tariffs, in general, are at present appreciably lower than the average bus fares. There would, therefore, appear to be a case for increasing them but the railway administrations are almost unanimous in their opinion that this would not be useful as more traffic, particularly the goods, would be lost to the road.

In case of the secondary lines forming parts of the national railway network in a country, the scale of tariffs is generally the same as that applicable to the ordinary lines. Any proposal for enhancement is strongly opposed by the public. On certain hill sections of the category 1 railway (Indian) enhanced tariffs were charged; they have been reduced by at least 25 %. It is argued that the areas served by the railways in category 1 have a strictly limited production capacity and the type of traffic offering cannot bear increased tariffs. In most of the areas, the motor competition is just beginning. Certain administrations (A.O.F. and Cameroons) hope that the reduction of the tariff might even attract more traffic.

Even though a general increase in tariffs — passenger and goods — may not be advisable, there appears, from the railway point of view, no case for withholding tariff adjustments in the case of monthly or season tickets for commuters or for withdrawing of concessions in rail travel given to students, etc. But such an action would evoke such serious social and political repercussions that it would not be agreed to by the Government. It may be mentioned that there are some railways of local interest in category 2 B where more than half the passenger traffic avails of the concession rates.

The rigidity and uniformity of tariffs is one of the vulnerable points in the armour of the light railways, specially in category 2 A and it would help their economic rehabilitation considerably had they the greater liberty and flexibility generally enjoyed by the road transport system. Railways in category 2 B have more liberty of action; they can negotiate special terms with their big clients for transport of their goods traffic but this is legally banned on the Indian Railways.

5.6. *Simplification of transport documents and the rate structure.* — All the railways who have replied to the questionnaire had been alive to this question already. On most of them, the travel documents have already been simplified to the extent possible. In fact, when goods or parcels have to go over long distances involving frequent handling enroute, careful documentation is indispensable.

Similarly the railways report that efforts are continually being made to simplify the rate structure and that there is no further scope for simplification as would attract more traffic to the railways.

5.7. *Reduction in the number of staff to economise on the running costs.* — To improve their economic balance sheet, this method offers the maximum scope for economies; this is particularly of significance on category 2 railways where labour costs have gone very high but this measure bristles with social and political difficulties. It evokes hostility from the unions, is disliked by the politicians and creates unemployment and other allied problems for the Government of the country affected. Reduction in staff has, however, been achieved, though not to the full extent possible, on many category 2 railways by :

(*a*) dieselisation (one man driving only);

(*b*) introducing the « single traffic regulator », C.T.C. or mechanised regulation;

(*c*) unstaffing certain stations by providing a reduced number of staff; at others by combining their duties;

and by closing certain stations during certain parts of the day and at night;

(*d*) providing replacement road services in place of the rail services involving the use and movement of large number of staff.

The problem of the survival of the light railways in category 2 is definitely linked up with the question of the better utilisation of and the reduction in the number of the staff. In this the unions can help the administrations by exercising their mature judgement and by having a long-range view of the problem and so can the national Governments by taking firm decisions in the matter however distasteful and full of political and social difficulties it may be. The Governments will have to assist the railways in finding jobs for the retrenched and prematurely retired employees of the railway.

5.8. *Reorganisation of light railways in a country in one separate system.* — This method (where feasible) by which all the light railways whether managed by private companies or forming part of the national network under State management is worth consideration. It has its advantages if the new management is permitted a good deal of flexibility and greater liberty of action than the national railway administrations are allowed with regard to simplification of operating measures, rationalisation of services and tariffs. Difficulties are bound to arise but can be overcome. It is understood that some transfer of sections from one management to another has already been effected on some European Railways. The nationalisation of some railways under private management was mooted in Sweden but since the prospects of improving their financial position did not appear bright, it was not pursued.

5.9. *Criteria for continuing a light railway in operation.* — This problem has been engaging the attention of some railway administrations in Europe and before the yardsticks developed by them are discussed, it would be better to state that in some cases purely technical and local reasons may compel the retention of a light railway though its financial position may be far from satisfactory. They are connected with :

(*a*) political and strategic policies of the Government involving the security of the country;

(*b*) topography of the country.
The Ardeche line (C.F.D.) and the Alpine railways in Switzerland have to be retained even under uneconomic conditions as it is extremely difficult for the road transports to obtain access to the regions served by the railways for the greater part of the year;

(*c*) climatic conditions.
Certain sections in Italy, such as the Padana Valley railway (I.T.C.), are affected by frequent mists which make road operation dangerous and are indispensable to the country's economy.

Barring the above and similar other exceptions, it is desirable to establish a yardstick to judge up to what stage a line with dwindling traffic should be kept open or whether it would be worthwhile investing additional sums of money in modernising it and improving its operation. The problem would be comparatively simple if the line in question is not linked up in any way with the main line system but becomes complex when it is so. In that case not only has the local traffic to be taken into account but also that which is common with the main line system and originates or terminates there.

The D.B. have a special organisation which has been making systematic enquiries as to whether a certain secondary line should continue to operate wholly or partially or be replaced. On the basis of their yardstick they recommended the closing down of about 900 miles of their light railways but the Federal Government of

West Germany is reluctant to accept the recommendations.

The S.N.C.F. have laid down that limiting conditions for keeping a secondary line open to traffic are that a minimum of 50 000 freight units of goods traffic and 200 000 passenger units must accrue per kilometre of the line per annum. This yardstick is less stringent than that proposed by the D.B.

For a light railway to continue in operation, the A.O.F. specify a more stringent criterion. It must earn annually 150 000 freight units per kilometre of the line. The passenger traffic can be converted into equivalent freight units by dividing the passenger units by 4. If this yardstick were to be applied, it will not be possible to save many light railways from extinction.

The Swedish State Railways have also under investigation the question of closing of about 600 miles of their secondary lines. The detailed methods they follow or the criteria they have laid down are not known. In any case each country must solve its own problem keeping in view the local conditions which play a far more important role in decisions on such matters than any purely academic or dogmatic approach.

CHAPTER 6.

RAIL-ROAD CO-ORDINATION.

6.1. *Present position of rail-road competition on light railways.* — On some category 1 railways (Medi-Niger, Mozambique) there is not much competition offered by the road transport system as it is just developing. The volume of traffic lost to road varies between 10 to 20 %. On others (Indian and C.G.R.), the railways are losing about 50 % of the total traffic available. On the railways in India the traffic is developing rapidly and therefore there is enough scope for both transport systems to co-exist side by side for some time. The South African railways are the largest motor transport operators and as the railway capacity is in deficit, the road transport is used to supplement it. The Franco-Ethiopian Railways are losing even their long distance traffic on account of the competition from the heavy motor transport running on the Addis Ababa-Assab highway (about 540 miles). And they have no road transport of their own. On the other hand, the A.O.F., Cameroons, Medi-Niger and Mozambique own subsidiary motor undertakings.

In the case of category 2 railways, the railway traffic suffers considerably from the competition offered by the car, the bus and the lorry, though it has not reached alarming proportions in Yugoslavia and Czechoslovakia where the development of motor transport has been slower than the industrial development during recent years. On category 2 B railways maximum losses have been suffered in goods traffic but marked losses have also been recorded by the passenger traffic on category 2 A and 2 B railways except on sections where concessional travelling forms the largest percentage of the passenger traffic. In plains and close to towns the privately owned light motor vehicles take away a good chunk of the railways' passenger traffic. In Italy and France the traffic taken away from the secondary lines is estimated at 50 to 80 % and on the S.J. Railways the passenger traffic declined by 18 % in six years from 1949-1955.

6.2. *Inherent advantages of the road transport system over railways.* — The road transport system scores over the railway because of its certain well known advantages, viz. its suitability for short distance traffic, its door to door service and its greater flexibility. In many countries which have very good high-speed roads and on which heavy transport (from 8 t to 20 t lorries) is developing it can become a threat even to long distance traffic in which field the railways have so far enjoyed a monopoly, particularly for the bulk transport of goods. Its competitive position, particularly as regards freight transport is much stronger than for pas-

senger transport as, in the former, small undertakings generally predominate and in most cases the lorry owner is also the driver. Although in point of cost of transport the railways have an advantage in their favour yet motor transport is able to offer services, sometimes even at lower tariffs. This class of transport does not bother about any transport obligations, fiscal or administrative controls and is able to carry away the cream of traffic, i.e. the one which is high-rated, regular and well balanced leaving unprofitable assignments to be executed by the railways. The lorry owner works long hours, overloads the lorry, puts off its maintenance, makes inadequate allowance for depreciation, generally flouts all road and labour regulations and on top of that is able to satisfy his customer down to the smallest detail. He starts with the initial advantage of not having to invest any capital on the construction or maintenance of the road system. Though he pays road taxes on the vehicles and taxes on the fuel, they do not constitute an equitable share for the construction, maintenance and extension of the road system.

Once the railways understand these inherent advantages of the road transport system they can equip themselves for meeting their adversary on its own ground and with its own weapon, i.e. by active participation in the road transport system themselves.

Another advantage which the road transport system has over the railways arises from the simplification of the relationship between itself and the client, simplification of documentation and tariffs. By and large, the mentality of the railway official, particularly on State owned undertakings is too far removed from developing a satisfactory and simple relationship with the client.

6.3. *Means adopted presently by light railways for meeting road competition.* — From the replies received it would appear that the light railways are directly or indirectly owned by the State. Even in privately owned companies shares are owned by the national Government, the Provincial Governments, Corporations and Communes. The road systems with very few exceptions are also constructed and maintained by the Government. The Governments have, therefore, been alive to the necessity of enabling the railways to meet the road competition.

It has already been stated that most of the African Railways with the exception of the Franco-Ethiopian Railway own supplementary motor transport undertakings. In India the passenger transport has been taken over by some of the States (Provinces) operated either directly or through subsidiary companies in which the railway has in many cases a controlling share. The freight transport is in the hands of the private companies but is likely to be taken over by the States after some time.

Light railways in category 2 B own their own road transport with which not only do they run replacement services for carrying passenger traffic but also serve as feeders to their railways. They do not, however, commonly run their own road freight services but category 2 A railways carry a good deal of the road freight traffic also; such, for example, are the Ö.B.B., S.J. and S.N.C.F. who function as carriers as well as assigning agents by chartering private lorries. This is the only way by which the railway would meet the adversary on its own ground and fight it with its own weapon. Consequently in some countries, the road transporters have begun to protest against the railways operating their own road services. In Austria and Switzerland regular passenger services are being run by the State Post Office and there is a good deal of rail-road co-ordination. In fact, the motor services provide an invaluable contribution to railway traffic.

6.4. *Methods suggested for improving railways' competitive position.* — No rail-road co-ordination plan or policy can be effective whether imposed by the Government or negotiated between the railways

and the private road undertakings unless the railways provide a bargaining counter by showing a superiority in some respects to the motor transport system. This is only possible if they put their own house in order by adopting technical improvements, providing better and faster and properly scheduled services, by introducing all possible economies in their operation and by providing comprehensive auxiliary services such as by contruction of private sidings, providing warehousing facilities and by making the relations between the railways and the clients as simple as possible. This can be achieved with the help of special agencies who can solve any problem coming between the client and the railway in a very expeditious manner and who can also secure traffic for the railways. By the use of containers, piggyback services and palletisation the advantage of door to door service provided by the road transport can be provided by the railways. They should not neglect parcel traffic which can be most paying. Its collection and delivery can be effected by means of motor vehicles.

Category 2 railways should no longer worry about short distance freight traffic as this is lost to the road transport for ever and is never likely to return to the railway. They should treat their secondary lines as distribution, collection and industrial sidings for securing long distance goods traffic going to or coming from the main line system.

Above all, the railway administrations should show initiative and mental flexibility with a view to offering better and quicker services, speed of delivery, simplicity of relationship with the clients and in the tariffs. In most cases it would be desirable that the road transport systems owned by the railways should not be operated directly but through subsidiary companies.

6.5. *Limitation and regulation of road transport system.* — From what has been stated earlier the following means can be adopted for regulation of the road transport system :

(*a*) imposition of a minimum tariff.

At present a maximum tariff has been laid down generally but no minimum has been laid down. This step may not, however, help much as road transport usually carries high-rated traffic for which its charges are generally not very much different from the charges levied by the railways;

(*b*) fixing and enforcing of maximum load limits;

(*c*) restriction of the sphere of its operation.

Licenses may be issued for running over a particular route or within a certain district or in a certain zone;

(*d*) insistence on observance of a standard of maintenance of the road transport unit to ensure greater safety of human life;

(*e*) obedience to Government regulations and control and imposition of heavy penalties in case of default.

A present the road transport undertakings are usually small and because of their scattered nature they are able to flout with impunity most of the Governmental regulations — technical, fiscal and administrative;

(*f*) levy of taxation adequate enough to meet an equitable share of the cost of construction, maintenance of the existing roads and the extensions thereof;

(*g*) enforcement of a standard of physical health and of eyesight for drivers, enforcement of working hours and other regulations controlling employment of labour.

6.6. *Need for a policy of rail-road coordination.* — As most of the railways belong to the national Government directly

or indirectly and as all the road systems are provided by the same Government, the need for an integrated policy for rail-road co-ordination is obvious. In permitting the railway administration to participate in the road transport services, politics should play no part, nor should the question like State versus private enterprise cloud the Government's judgment. It is understood that in almost all countries plans for rail-road co-ordination are being actively pursued and beginnings have been made. It is in the overall interest of the country that an orderly and balanced development of all forms of land surface transport should be organised and achieved at an early date and steps should be taken to eliminate avoidable and wasteful competition between different forms of transport. In the ultimate analysis it is to the national advantage that a particular form of transport is confined to a sphere where it is more suited and economical both from the point of view of initial cost and in maintenance.

CHAPTER 7.

CO-ORDINATION OF INVESTMENTS.

7.1. *Sources of capital for construction and renewal of railways and roads.* — It appears from the replies received that category 1 and 2 A railways derive, with minor exceptions, their capital investments from the national governments of the countries they traverse. The increased investments and funds for renewals for category 2 B are derived from the government or from public funds vested in the provincial, municipal or local autonomous bodies.

The same sources, with very few exceptions, generally provide capital for the construction of the road system and the extension or renewal thereof. The capital invested in the road vehicles is mostly private in origin, the only exceptions being the following :

(*a*) Governmental authorities (as in India and Switzerland).

(*b*) Railway administrations who own fleets of road transport of their own.

Even in the case of private vehicles and small road undertakings the source of the capital may be traced to the banking institutions and similar other public developmental organisations.

In the ultimate analysis, therefore, the investment sources are identical.

7.2. *Desirability of a co-ordinated policy for investments.* — If both the transport systems draw their strength and vitality from the same source directly or indirectly it stands to reason, than it is most undesirable that there should be a cut-throat competition between the two systems leading to frittering away of the national resources and to financial losses to either of the systems. As already stated in the report, the railway systems in Europe and elsewhere have suffered considerably on account of this.

The following suggestions are offered for co-ordination of capital investments and for the orientation of national policies concerning future developments of the rail and road transport systems :

(*a*) On the railway side :

(i) by closing of the sections of secondary lines on which traffic has declined considerably and where its recovery is impossible. The replacement services should be provided by the road transport system;

(ii) by drastic revisions in operational and organisational methods with a view to maximum economy.

The railway services should be supplemented, where necessary, by road services. Particularly this refers to those secondary lines where their functions are not replaceable;

(iii) by permitting the railway administrations to participate in the road services without any let or hindrance.

(*b*) On the road transport side :

(i) by refusing funds for construction of or improvements to road systems running parallel to existing railway network, the functions of which the road transport system can never completely or economically take over;

(ii) by restricting through legislation or by mutual agreements between the two transport systems, the scope and sphere of usefulness of each means of transport;

(iii) by confining the operation of the road transport system to a sphere where its inherent advantages of door to door service and greater flexibility can have full economic value.

This is possible in short distance hauls. Thus licenses should be issued for operation over a route or a district or a well defined region;

(iv) by banning the construction or import of heavy road vehicles (20 t and over).

Investment in such transport would be against the national interest as it would tend to wean away heavy traffic from the railways. Further, it overloads the existing road systems which have been designed and built primarily for light vehicles, both for passenger and goods traffic. Such steps, it is understood, have already been taken in Switzerland and U.K. but not so far in Italy, Germany and France and other countries.

As already stated in the report, the transport of goods traffic is mostly in the hands of mushroom type of small undertakings which makes their effective control and regulation very difficult. It would, therefore, be in the national interest if the road transport systems are, in all countries, reorganised into large public undertakings under the control of either the national or provincial governments. The small undertakings can provide auxiliary services in restricted fields or can serve as subsidiaries to the large public undertakings or merge with them. The railway administrations should also be permitted to hold a substantial interest in these public undertakings.

CHAPTER 8.

RESUME.

It is not easy to provide a completely satisfactory definition of the term « light railways » as its meaning and connotation have undergone profound changes during the last quarter of a century. The « light railways » now include not only those railways originally built with light constructional features for developing certain inaccessible and less advanced regions of a country but also those railways which were provided to serve the secondary transport needs of communities. The definition included in the questionnaire was the best possible.

The importance of the light railways for the development of a region or for supplying secondary transport needs has rapidly declined with the advent of the road transport system.

On account of the unsatisfactory or ambiguous definition, some railway administrations did not supply the basic information regarding their light railways. The total length of about 36 000 miles as obtained from the replies received, therefore, does not indicate their true length which must be far higher. According to the information received they at present constitute in the aggregate about 22 %

of the total railway mileage of the countries which replied to the questionnaire.

During the last two decades, the development of the light railways has been negligible. In fact, due to declining traffic resulting from keen road competition considerable lengths (over 33 % of the present mileage) had to be closed down to traffic either partially or entirely.

In all cases alternative replacement services were provided by the road transport system either run by the railway companies themselves, their subsidiaries or by private undertakings. Such services have fulfilled adequately the needs of the communities they serve.

Economic considerations would indicate that, where feasible, changeover to the diesel traction would enable many light railways to survive the road competition, but in several countries adequate resources are not available for dieselisation of their light railways as investments have to be diverted to satisfy more pressing needs. Already many light railways in Europe and Africa have been wholly or partially dieselised and have thereby improved their economic position.

Electrification of light railways on account of the high capital cost involved is, in most cases, not financially justified because of the low traffic potential. Under special conditions, however, electric traction has been utilized advantageously on some light railways in Europe.

Many railway administrations have no clear-cut demarcation between their light railways and their ordinary lines; so they do not keep any separate statistics. From the operating and other statistics, albeit incomplete, supplied by railway administrations who maintain separate statistics it would appear that the basic laws governing the railway operation affecting their light railways are identical to those governing their other lines.

For the light railways to survive the road transport competition, the railway administrations have already carried out considerable operational reorganisations and simplifications and staff reductions to achieve maximum economy combined with optimum operating efficiency. These profound changes include the use of road transport services for passenger and sometimes for freight and parcel traffic. They have thus been able to put up a good fight against their adversary with its own weapon. The working of the light railways, particularly in Europe, now differs considerably from the working of the main line railways.

It would appear that sources of the capital invested in the light railways, the roads and even in the road vehicles (excluding the private vehicles, of course) directly or indirectly are identical, viz. Government or public funds. It is, therefore, imperative that the Governments of countries concerned should ensure by legislation or otherwise that each of the forms of land surface transport operates economically and efficiently in the sphere for which it is best suited both from the point of view of the capital cost and maintenance and that there is no wasteful competition which would fritter away the national assets.

Though with Government help envisaged in para above, with abandonment of their unprofitable sections and with their active participation in road transport services, the light railway administrations may stay in business yet this would be a poor consolation as, in this process, many of them would tend to become road transport operators and would cease to be railwaymen ultimately.

SUMMARIES.

1. — A « light railway » (chemin de fer économique) is a railway for which economy, either from the point of view of construction, or maintenance or operating, is the main consideration.

2. — From the point of view of the means to be adopted to reduce operating costs and to determine the resulting struc-

tural changes, the following categories may be distinguished :

1) the light railways in countries with rapidly developing economies;

2) the light railways in highly developed countries :

   a) the small networks or isolated lines operated by private companies, generally under government control;

   b) the secondary lines belonging to large national railways, which are State operated or controlled.

3. — On the basis of the information supplied, the light railways constitute about 22 % of the total route mileage of the countries wherein they exist.

During the last two decades, there has been very little extension of light railways, a fact which may be attributed to the rapid development of the internal combustion engine in its application to road transport.

4. — Light railways of category 2 (*a* and *b*) have been reduced by 31 %. In the three categories as a whole, there has been about a 25 % reduction in the initial mileage, the substitute road services being operated by the light railways or their subsidiary companies, or by private firms, either on contract or not.

5. — As most of the light railways do not establish any statistics or did not supply sufficient operating data, it is not possible to formulate any general conclusions.

6. — From the replies received, it appears that the following methods have been adopted to reduce the operating costs :

a) introduction of some elements of mechanisation in laying and maintaining the permanent way;

b) progressive abandonment of steam traction and its replacement by diesel traction (150 to 450 HP railcars, 550 to 850 HP locomotives) and, in certain cases, by electric traction;

c) simplification of the signalling and operating methods;

d) doing away with the traditional subdivision of the staff into different departments (employees available for multiple duties);

e) having the traction units driven by one man (one man cars);

f) progressive replacement of lines remaining unprofitable despite the application of various methods of rationalisation, by road services, run as part of the railway undertaking;

g) simplification and perfecting of the transport documents.

7. — The dividing line between electrification and dieselisation is a matter to be decided by each undertaking. However, on the whole, it can be stated that the general tendency is towards dieselisation.

Electrification appears to be reserved for mountain lines, connections with systems that are already electrified, and for countries where the price of fuel is high.

8. — The financial rehabilitation of the light railways would be considerably facilitated if they enjoyed greater liberty and more flexible tariffs, as is the case in general with independent road transport services.

In certain cases, the light railways could meet competition by participating in the road services. On the other hand, the independent road transport firms should be obliged to adhere strictly to the road traffic and labour regulations, and more effective fiscal and administrative control should be introduced, in order to make their respective positions equivalent and consequently equitable.

9. — If the efforts made by the light railways to improve their position have proved fruitless, a programme to replace the lines showing the greatest deficit by road services can be considered, which may eventually make up for part of the losses

on the lines kept open. A mixed solution can be considered in which motor transport would replace the railway services during slack hours, so that the line can be closed down for part of the day (stations, signalling, etc.).

In certain cases, partial cancellation of the services can be considered (doing away with the passenger or freight services).

10. — If all these combined efforts do not result in a satisfactory solution to the problem of financial stability; but for political, strategic, topographical or climatic conditions, the line has to be kept open, it is up to the Government or other authorities concerned to take the necessary steps.

11. — The grouping together of all the light railways of a country is a matter deserving consideration, so long as this is compatible with greater flexibility and greater freedom of action as regards the simplification of operating measures, and the rationalisation of the services and tariffs.

12. — In the case of certain national systems, the advisability of separating, within the system itself, the light railway lines from the main lines, as regards the regulations operating and accounts, is under consideration.

13. — The standards which can be applied in order to obtain satisfactory and efficient rail-road co-ordination depend upon those factors forming the advantages road transport possesses over the light railways : door to door services, greater flexibility, simplification of relations with clients, reduction to the minimum of indirect and general costs, lower capital investments.

The technical measures and organisation measures which may be considered in the case of rail-road co-ordination involve the intervention of the main line railway.

In addtion, the Government must intervene effectively in order to avoid competition against the lines finally maintained in service.

14. — In order to improve the returns from the capital available for the transport industry, the following principles should govern any investments :

a) to develop in extent and improve in quality the inland road network, in order to absorb the traffic (passenger and freight) from the secondary lines to be closed down, rather than make important great and long motor arteries for heavy motor transport, parallel to the main lines of the main railways;

b) to orientate motor construction and road traffic standards towards limiting the dimensions and loads of road vehicles, so as to avoid the development of large capacity motor vehicles and trailers, whose presence upon the roads is the cause of the inadequacy of the road network and involves capital expenditure upon new roads to a far greater extent than would be needed for private vehicles and vehicles of average tonnage.

Such measures are within the competence of the Governments.